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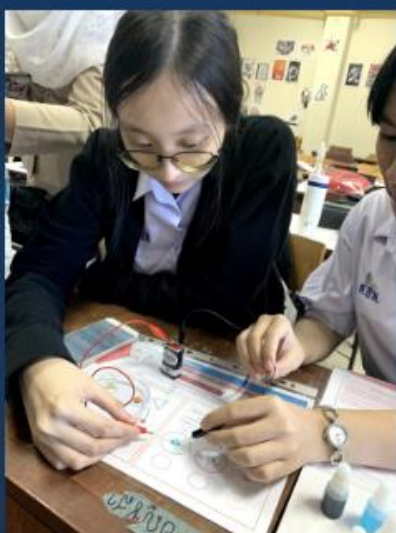
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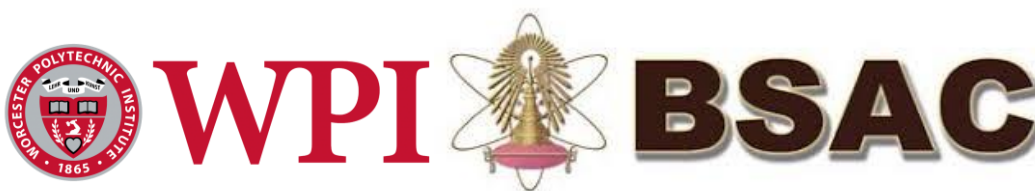
PROMOTING SCIENCE EDUCATION IN THAILAND WITH SMALL-SCALE CHEMISTRY EXPERIMENTS



WPI



**By: Rosemarie Awada, Andrea Fialli, Benyapha Phoomtrakul, Pattarawimon Phoonsiri,
Allison Silvia, Wuttikorn Torprasertkul, and Pichaya Watthanawareekun**



PROMOTING SCIENCE EDUCATION IN THAILAND WITH SMALL-SCALE CHEMISTRY EXPERIMENTS

Sponsored by:
DOW Thailand Group



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An Interactive Qualifying Project (IQP) submitted to the faculty of Worcester Polytechnic Institute and an Interactive Social Science Project (ISSP) Submitted to the Faculty of Science at Chulalongkorn University in partial fulfilment of the requirements for the Bachelor Degree of Science

This report represents the work of three Worcester Polytechnic Institute undergraduate students and four Chulalongkorn University students submitted to the faculty as evidence of completion of a degree requirement. Worcester Polytechnic Institute routinely publishes these reports on its website without editorial or peer review. For more information about the projects program at Worcester Polytechnic Institute, please see: <http://www.wpi.edu/Academics/Projects>.

ABSTRACT

In this project, we investigated how small-scale chemistry experiments increased student interest in science. DOW teachers received training and kits for their classroom that include small-scale laboratory materials. Students and teachers in various schools were surveyed and interviewed. We found that small-scale experiments were cheaper, easier to implement, and piqued student interest in science. However, less experienced teachers from under-funded schools struggled to implement the experiments. We recommend resources such as handbooks, training, and a network to support these teachers.

EXECUTIVE SUMMARY

The Problem

Though Thailand has made significant economic improvements over the last few decades, the country's STEM education system is not up to the standards of its competitors ([The World Bank, 2019](#)). Thailand struggles to distribute educational funds equally across the country and there is a large inequity of resource availability between advanced and underprivileged schools ([OECD/UNESCO, 2016](#)). In addition to unequal funding, Thailand also faces a lack of teachers qualified to teach science education in both rural and urban schools ([Atagi, 2011](#)). Improvements in the Thai education system aim to generate an interest in science in the future generations of the Thai workforce.

To generate a greater passion for science in Thai youths, our sponsor, the DOW Thailand Group, has created a program titled the DOW Chemistry Classroom, which trains high school teachers in small-scale chemistry techniques. Small-scale chemistry uses miniature plastic apparatuses, as opposed to full-size glassware, and uses less than 100 times the amount of chemicals compared to full-scale laboratories. The small-scale science experiments offer multiple benefits to students' education such as safety, lower overall cost, and less time to prepare solutions ([Boyd, 2014](#)). Due to the reduced cost and time, classrooms in developing countries are able to implement hands-on learning into their science curriculum to improve students' engagement and interest in science ([UNESCO, 2015](#)). Dr. Prof. Supawan Tantayanon, founder of the DOW Chemistry Classroom, explained that there are introductory training sessions open to the public as well as advanced training sessions for specially selected "outstanding teachers" to teach them small-scale chemistry skills.



School Classroom in Rayong

Our Goal

The goal of this project was to evaluate how the DOW Chemistry Classroom has influenced Thai youth's interest in science. We developed four objectives to analyze different aspects of the DOW Chemistry Classroom:

1. Conduct interviews and surveys to determine if the DOW program has led to increased student interest in science
2. Evaluate student's emotional reactions to the small-scale experiments

3. Evaluate if DOW teachers have the desire, skills, and confidence to implement small-scale experiments into their classrooms
4. Provide recommendations for how the DOW Chemistry Classroom could increase student interest in science in the future

Our Research Design

To complete our objectives, we utilized research methods such as surveys and interviews to collect our data. We analyzed information from both students and teachers to identify strengths and weaknesses of the program. All survey questions were written on a five-point scale from strongly disagree to strongly agree. Our student surveys focused on identifying if students were interested in science, if their interest was impacted by outside factors, and if they had positive reactions to the small-scale experiments. During student interviews, we asked similar questions to understand the student's personal story of how their interest in science developed. Our teacher surveys focused on assessing teachers' confidence in their teaching skills and their opinions on the DOW training program. Our interviews with teachers focused more on the benefits and challenges of implementing small-scale experiments into their classrooms and any recommendations they had for the program.



Team Visits to Schools

Key Findings

From our observations, interviews, and surveys we identified several findings.

1. Students in DOW schools have a greater interest in science than students in non-DOW schools.

We compared the responses of non-DOW and DOW students for three different questions regarding student interest: “I plan to use science in my future career”, “I like my science class”, and “I am interested in careers that use science”. We performed a two-sample t-test and found that the average response for all three questions was higher in DOW students.

2. Schools with greater lab quality have greater student interest in science.

After visiting schools and conducting interviews, we were able to assign each school a “lab quality score” to compare if students with better labs had a greater interest in science. A school's lab quality score was decided based on the number of students in a lab group, how often students completed experiments, and the quality of their lab materials. We found that as lab quality increased, the average score for the science interest questions also increased.

3. DOW schools have a higher lab quality

This finding does not necessarily mean that using DOW causes a school to have a higher lab quality; more extensive analysis would have to be completed to prove this. However, we did learn through our interviews that using small-scale experiments allows teachers to complete labs more frequently, which would increase their lab quality.

This finding could also be biased since the DOW schools that we visited were considered to be “outstanding schools” and had won various awards. The average lab quality among all DOW schools, not just the outstanding ones, could possibly be lower in our target population; an additional study with a larger sample size would need to be conducted to confirm or deny this.

4. Factors outside the classroom have an impact on students’ career decisions

We compared student responses for their future career to various questions: “My parents would like it if I chose a science career”, “I am able to get a good grade in my science class” and “My teacher makes fun to learn”. Social cognitive career theory explains that factors such as family pressures, self-efficacy, or teachers/role-models can impact a students’ career choices. We found that all of these factors had a significant correlation with students’ career plans, but that parents had the largest impact of the three.

5. DOW teachers are confident in their teaching skills

In teacher surveys, we found high responses to questions under the “teaching confidence” category from teachers that are trained by DOW. This displays that many of these teachers feel confident in their ability to teach their class. Their confidence cannot entirely be attributed to DOW since we did not have a control group for comparison, but it is important to note that teachers who completed DOW training generally felt confident teaching.

6. Teachers think the DOW training benefits their classroom

We found that teachers generally believed that the DOW training was useful, and they were able to take the skills they learned and implement experiments into their classrooms. Teachers also expressed in interviews that small-scale was easier to run than full-scale because it took less time to set up; however, most teachers still felt it was important to teach full-scale techniques. While they believed that the small-scale lab experiments were successful in capturing student attention, some teachers struggled to adapt the experiments or create new experiments on their own, as they lacked a formal chemistry education.

Recommendations for the DOW Program

1. Creation of an experiment handbook and tutorial videos

Many teachers expressed difficulties being able to adapt the experiments taught at the training to fit their classroom. Some teachers also noted they had trouble remembering the experiments they learned after they left the DOW training. An online or printed handbook could be provided to teachers trained by DOW that has examples of all experiments possible to complete with the given kits. An online version could allow teachers to upload their own

experiments and would be more easily adaptable for changes. In addition, many teachers suggested YouTube tutorial videos of how to set up and complete the experiments.

2. Adapt the experiments for primary schools

An adaptation of the kits to fit primary school curriculum could allow an earlier exposure to hands-on science experiments. This could hopefully introduce students to laboratories at a younger age and promote an interest in science early in their education.

3. Creation of a teacher networking platform

A social networking platform could be used as a way for teachers to communicate ideas, ask questions, and collaborate. This could be done on Facebook, LINE, etc.

4. Increase opportunities for non-outstanding teachers

Subsequent trainings could be implemented for all teachers, especially the teachers that are not considered “outstanding” and do not have the chance to be selected for additional advanced training. These are the teachers that would benefit the most from follow-up trainings since they do not have the chemistry knowledge to design their own experiments.

5. Better communication between DOW Thailand Group and teachers

To avoid teachers losing contact with DOW once leaving the training, DOW could potentially work on sending out more emails or using LINE phone app to more consistently keep in contact with the teachers who use the program. The teachers would more regularly be given updates on new training programs and new experiments.

6. Increase advertisement for the DOW Chemistry Classroom

Advertising methods could be expanded in order to reach more teachers and schools that do not use the DOW program. They should target under-funded schools with no lab materials, since they would benefit most from the low-cost small-scale experiments, and increase in advertisements to these schools via LINE or Facebook.

7. Include students and parents

DOW could have an event where parents can bring their children to gain some hands-on experience and see demonstrations of relatable small-scale experiments. Possibly, this could be a showcase of the outstanding teachers’ small-scale ideas or it could be run by DOW staff entirely. The hope is to increase students’ interest in science in a non-academic setting and expose parents to the benefits of science education since they have such an impact on student career choice.

8. Create a volunteer program

Several teachers suggested creating a volunteer opportunity for the teachers trained by DOW to visit schools who lack lab quality and a strong science education. This would expand the program in Thailand and allow more schools to benefit from the small-scale experiments.

9. Make a monthly competition and newsletter

If a social networking group was created for teachers, a monthly update or newsletter could be sent out in this group to keep the teachers engaged. This newsletter could include new experiments, new resources, and a competition; at the beginning of each month, teachers could submit a novel experiment, apparatus, or idea to DOW and the winner could be announced at the end of every month in the newsletter. The idea is to keep teachers thinking about new ways to improve the experiments and would provide a widespread benefit to all involved.

10. Provide scholarship for funding lab kits

Since many DOW teachers that teach in under-funded schools have to use their own salary to buy small-scale lab equipment for their class without getting financial support from their school, there are often a small number of kits being used by a large group of students. DOW could start a scholarship program that provides funding to under-funded teachers for new lab materials. Teachers who want to apply for scholarship funding could submit an application demonstrating their financial need and how they utilize the small-scale labs in their classroom.

Recommendations for a Follow-Up Study

1. Expand the sample size and diversity of surveyed DOW schools

It would be beneficial to assess a larger and more diverse sample of schools that use DOW small-scale experiments that includes more “non-outstanding” schools in order to ensure the conclusions from the data is accurate of the whole program and not just those who are successful.

2. Expand the sample size to non-DOW schools

We believe it would be beneficial to collect more science interest data from schools who have not participated in the DOW Chemistry Classroom small-scale experiments and have only performed full-scale experiments and theoretical science class. The student survey data collected from these schools could be compared to data from schools that use small-scale. This would allow a thorough assessment of the program's success in science education.

3. Collect enrollment data for science majors

Collecting enrollment data would be beneficial to identify the success of the DOW Chemistry Classroom. The number of students that pursue a science major in high school and how many students continued their science education in university since the creation of the program could be used to assess students' interest in science due to the implementation of small-scale chemistry.

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LIST OF ACRONYMS

ACS	American Chemical Society
A/SA	Agree/Strongly Agree
ASCI	Attitude towards the Aspects of Chemistry Inventory
BSAC	Bachelor of Science in Applied Chemistry
CST	Chemical Society of Thailand
IPST	Institute for the Promotion of Teaching Science and Technology
IUPAC	International Union for Pure and Applied Chemistry
MOE	Ministry of Education
NSM	National Science Museum
OECD	The Organization for Economic Cooperation and Development
O-NET	Ordinary National Educational Test (standardized testing used in Thailand)
PBL	Project Based Learning
PISA	Programme for International Student Assessment
PACCON	Pure and Applied Chemistry International Conference
RADMASTE	Research and Development in Mathematics, Science, and Technology Education
SCCT	Social Cognitive Career Theory
SSCL	Small-Scale Chemistry Laboratory
STEM	Science, Technology, Engineering, and Mathematics
UNESCO	United Nation Educational, Scientific and Cultural Organization

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Chapter 1: Introduction



CHAPTER 1: INTRODUCTION

Though Thailand has made significant economic improvements over the last few decades, the country's STEM education system is not up to the standards of its competitors ([The World Bank, 2019](#)). The Thai government plans to increase the number of STEM workers in order to improve the economy, sustainability, and overall status of Thailand. To do so, a twenty year plan termed *Thailand 4.0* has been implemented to encourage growth of the STEM workforce ([Royal Thai Embassy, 2020a](#)). In particular, the Thai education system is being targeted for improvements in order to generate an interest in science in the future generations of the workforce in Thailand.

The quality of the Thai education system varies significantly throughout the country. The access to high quality resources and qualified teachers differs between the urban and rural communities which has a significant impact on the students' education. Within the city of Bangkok, students consistently obtain high standardized test scores while the rural areas' scores vary between medium and low performance year to year ([Educational Testing Institute, 2019](#)). Creating a more equal quality of science education throughout Thailand is a key focus for the Thai government to improve the living standards and quality of life in the country.

Other developing countries have aimed to rectify a lack of workers in the STEM field by implementing various youth science education programs in order to improve STEM education. Countries in South America have developed informal science fairs and hands-on experiments that have generated a greater interest in science ([Ferreira et al, 2019](#); [Carriazo, 2019](#)). In Turkey, a program for pre-service teachers encouraged them to use laboratory techniques in elementary schools ([Johnson et al., 2019](#)). A program in Michigan, U.S. works with teachers to overcome their personal obstacles in their STEM classrooms to provide help in their specific areas of struggle ([Berzina-Pitcher, 2017](#)). The success of these programs was determined by measuring if and how students' love for science increased and if teachers felt more prepared in teaching their classrooms. This was done through qualitative observations and surveys that were analyzed quantitatively to recognize areas of strengths and weaknesses. In order to quantify improvement, surveys were given before and after the programs. The results obtained were essential to analyzing if the programs influenced the quality of teaching as well as the youth's love for science.

To generate a greater passion for science in Thai youths, our sponsor, the DOW Thailand Group, has created a program titled the DOW Chemistry Classroom. In cooperation with the Chemical Society of Thailand and National Science

Museum, the DOW Chemistry Classroom program trains Thai teachers at the high school and



Youths Completing a DOW Small-Scale Chemistry Experiment

middle school level on how to effectively implement small-scale chemistry experiments in their classrooms ([Tisadondilok, 2017](#)). Their hope is that giving teachers the tools to perform these experiments in their classrooms will aid in capturing students' interest in science in providing a quality education through laboratory experience.

In this project we were given the opportunity to investigate the DOW Chemistry Classroom small-scale experiments with the purpose of measuring the success of these experiments in increasing student interest in science. To do this, our team determined if the students were inspired to pursue careers in science, if the experiments used in classrooms were informative and engaging, and if the teachers were confident, properly trained, and desired to implement small-scale experiments into their classroom. We interviewed and surveyed both teachers and students to collect this data. Our findings were analyzed to provide recommendations to the DOW Chemistry Classroom so the program can further increase student interest in science. We found there is a potential for the DOW Chemistry Classroom to expand to a wider group of teachers so the small-scale experiments can be implemented in a greater number of classrooms in Thailand and internationally.

Chapter 2: Background

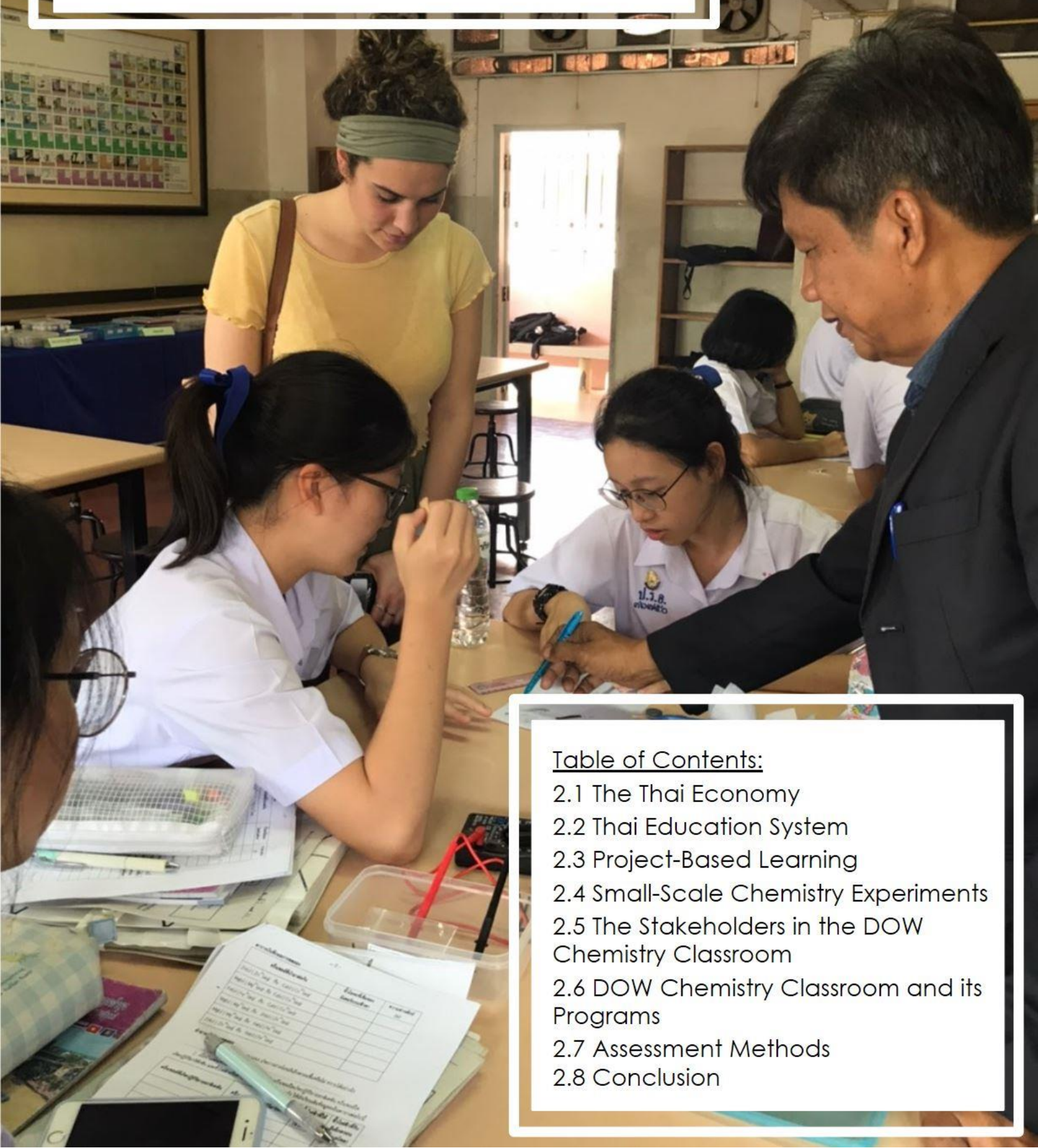


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CHAPTER 2: BACKGROUND

Out of 139 countries evaluated, Thailand ranks 79th in the quality of their math and science education ([Baller, 2016](#)). In an attempt to improve the Thai science education system, the DOW Thailand Group and the Chemical Society of Thailand implemented a new program in 2013 termed the DOW Chemistry Classroom. The DOW Chemistry Classroom trains teachers with innovative, relatable, and environmentally sustainable laboratory skills to be integrated into their classrooms. The hope is to increase the youth's interest in science by providing engaging small-scale laboratory experiments. If successful, an increase in the number of students studying science at a university can lead to more people entering the science workforce, thus leading to economic growth and development for the country of Thailand.

In this chapter, we begin with a brief overview of the Thai economy and its current initiatives to become more innovative. Next, we explain the Thai education system and factors that impact student learning. We then discuss our sponsor, the DOW Thailand Group, and other key stakeholders involved in the DOW Chemistry Classroom. We conclude this c with descriptions of programs comparable to the DOW Chemistry Classroom and the benefits and challenges that these programs faced during the assessment of the programs.

2.1 The Thai Economy

Over the last few decades, Thailand has made impressive strides in social and economic development. In less than a generation, they have moved from a low-income to upper-middle income country ([The World Bank, 2019](#)). There has been a decline in poverty, an increase in average years of education, and an increase in the number of people covered by health insurance. Though Thailand has made significant progress, the country has been trying to become even more innovative and economically competitive.

According to Khayyat and Lee ([2015](#)) in order to enhance a country's rate of innovation, competitiveness, and development, researchers have recommended the following: (1) allocate a significant budget to enhance science education, education enrollment rates, and internet connectivity, (2) modify school curriculum to emphasize creativity, and (3) encourage local organizations to conduct programs that promote innovation.

As of 2017, the mean years of schooling for the population of Thailand was 7.6 years; this statistic includes students currently in school as well as working adults. If current patterns of age-specific enrollment rates continue, today's Thai students can expect to go to school for an average of 14.7 years ([United Nations Development Programme, 2018](#)). These data points make it clear that the expectations for years of education in Thailand are rising, and the next generation of Thai youths will be far more educated than the generations before them. However, the years of schooling that students receive cannot be equated with the quality of their education. The average Thai student can expect to complete 12.4 years of school by the age of 18, but when the quality of schooling is factored in and what the students are learning in comparison to top performing countries, Thai students only receive about 8.6 years' worth of learning ([The World Bank, 2019](#)).

2.1.1 Thailand 4.0

The Royal Thai Embassy (2020) has outlined a plan for social and economic growth titled *Thailand 4.0* to continue their growth. As stated on their website, there are four main objectives of the *Thailand 4.0* plan:

- (1) **Economic Prosperity** - create an economy driven by innovation, technology, and creativity to increase research and development expenditures and improve the economic growth rate within five years
- (2) **Social Well-Being** - reduce social disparity, transform the welfare system, and develop traditional farmers into smart farmers
- (3) **Raise Human Values** - provide Thai people with 21st century skills, and ensure that at least five Thai universities are ranked among the world's top 100 higher education institutions
- (4) **Environmental Protection** - change Thailand to a livable country capable of adjusting to climate change and becoming a low carbon society

With these new initiatives, Thailand has a high demand for technical workers in STEM but there is a shortage of graduates entering the workforce. In 2013, a total of 359,521 vocational and technical students graduated at all degree levels, but less than half of those students entered the workforce, even with the abundance of open positions. In 2017, only 30.36% of available positions in the technical field were filled (Mongkhonvanit, 2017). The demand for technical workers has only continued to increase; the Thai Government predicts that Thailand will need 107,000 more STEM graduates in the next four years to fill open positions. Several factors could play a role in this staggering statistic, and *Thailand 4.0* aims to develop a stronger STEM community by starting at lower levels in the chain, such as the education system. In attempts to meet the high demand, *Thailand 4.0* puts emphasis on workforce development in youth schools (Barsam, 2019).

The *Thailand 4.0* goal of creating an economy based around innovation cannot be achieved if there are not enough STEM students heading into the workforce (Barsam, 2019). Thailand must be sure to put emphasis on workforce development and programs that encourage workers to become highly skilled in STEM disciplines. Rothwell's (2013) research shows that having more workers in STEM fields also plays a direct role in driving economic growth as a whole. Areas with high concentrations of STEM workers were found to have higher job growth, employment rates, patenting, wages, and exports as well as lower income inequality (Rothwell, 2013). Additionally, increasing the number of STEM graduates also creates external benefits for workers not in STEM fields. One study shows that there seems to be a positive effect of STEM graduates on the wages of workers without college degrees and workers with degrees in non-STEM fields (Winters, 2014).

2.2 Thai Education System

Over the last twenty years, the formal Thai Education system has evolved due to new acts and reforms that improved the education of Thailand's future workforce. In 1999, the National Education Act increased the average years of compulsory education from six to nine years. The act enabled up to twelve years of public education to be provided for free (Bureau of International Cooperation Ministry of Education: Thailand, 2017). This includes pre-primary,

primary and secondary education, also referred to as *prathom* and *mathayom* in Thailand. Overall, the application of the act has caused enrollment rates to increase throughout Thailand, but the quality of the education remains the true challenge (Fleischer et al., 2018).

Although Thailand's public expenditure on education is one of the highest in the region, 4% of the GDP, the quality of their education is not indicative of the large amount of money dedicated to the education system (Fleischer et al., 2018). The Programme for International Student Assessment (PISA) measures students' performance in science, math and reading (OECD, 1999). Out of the 69 countries surveyed using the PISA, Thailand ranked 53rd in science education. *Figure 1B (right)* compares Thailand's PISA scores to several surrounding ASEAN countries scores in the three subjects. As displayed by the graph, Thailand's scores are significantly lower than the Organization for Economic Cooperation and Development's (OECD) average and several other countries. Additionally, *Figure 1A (left)* displays Thailand's PISA scores 2003 through 2015. Specifically, when the 2012 scores are compared to the 2015 scores, the scores have decreased over time despite the large amount of funds supporting education (Fleischer et al., 2018). In 2018, Thailand's PISA scores continued to be significantly lower than the OECD average scores in science, mathematics and reading (Avvisati et al., 2019). The OECD and UNESCO links inefficient and inequitable distribution of resources as key components that have hindered the success of the education investment (Fleischer et al., 2018).

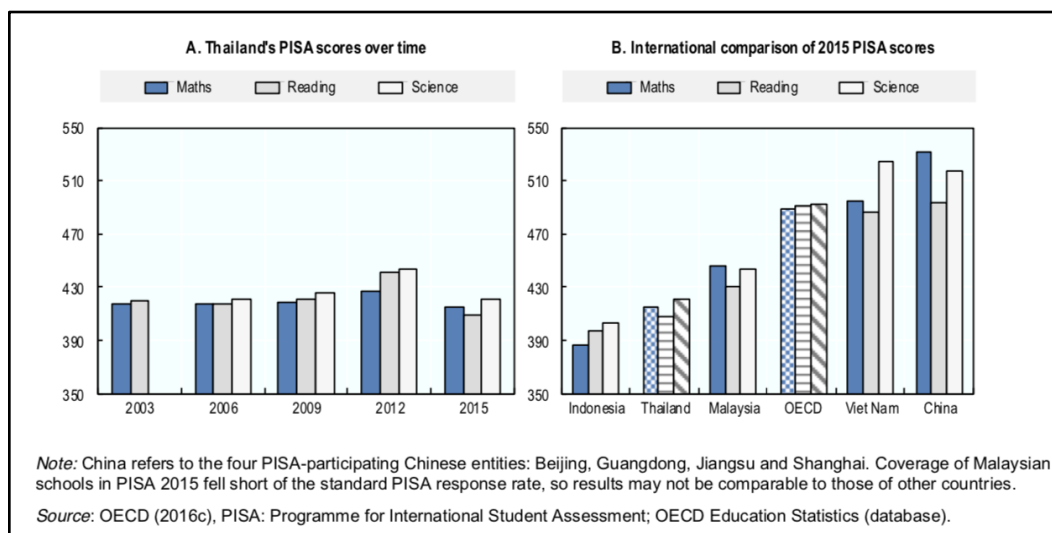


Figure 1: Thailand PISA Scores from 2003 to 2015 (Fleischer et al., 2018)

Furthermore, Thailand struggles to distribute educational funds equally across the country. *Figure 2* below displays the OECD report of resource allocation. Thailand is below average in equity of resource allocation in comparison to other select countries. Similarly, the inequity of resource availability between advanced and underprivileged schools is the second largest of the surveyed countries. (OECD/UNESCO, 2016). Therefore, small, minority, rural schools face education limitations due to a lack of resources.

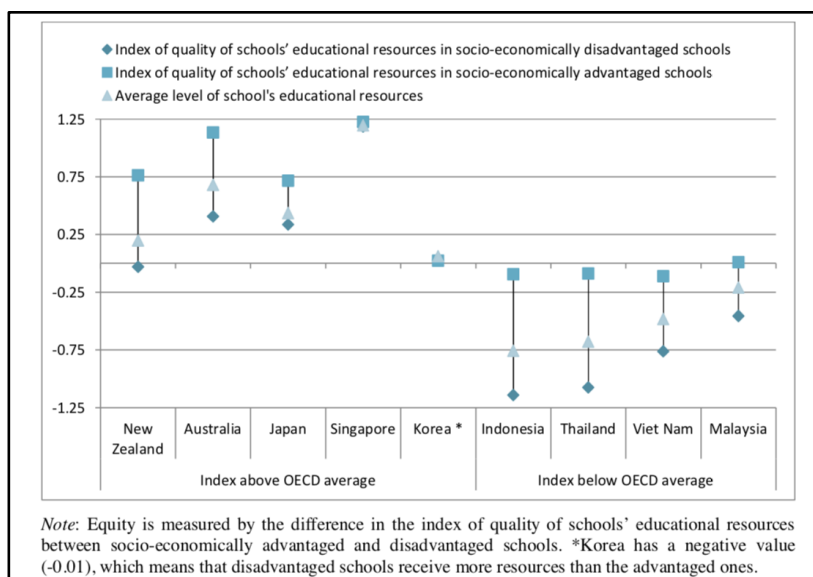


Figure 2: Equality in resource allocation, selected countries, 2012
(OECD/UNESCO, 2016)

In addition to the disparity of resources distributed among the rural and urban schools, the quality of education in each region varies (Atagi, 2011). The Office for National Education Standards and Quality Assessment revealed one-fifth of Thai schools do not pass minimum quality standards, most of which are located in rural areas (Fleischer et al., 2018). Teachers' qualifications are the most prominent variant in education quality by region. Twenty percent of teachers in urban areas, such as Bangkok, have a graduate degree in comparison to nine percent in rural northern areas (Fleischer et al., 2018).

Specifically, the lack of teachers who are qualified to teach science education is an obstacle faced in both the rural and urban schools (Atagi, 2011). In 2013/14, the demand for qualified science teachers, compared to other subjects, was the most prevalent in Thailand with a need of 6,173 teachers as displayed in Appendix A1 (OECD/UNESCO, 2016). A study completed in 2002 and 2013 evaluated how a lack of qualified teachers hinders the school's capacity for learning. As shown in Figure 3 below, the study revealed that over fifty percent of students in rural communities claim that the school is hindered by a lack of qualified teachers. This value is well above the OECD average of twelve percent. (OECD/UNESCO, 2016). Teachers in Thailand face many challenges when implementing science into the classroom due to the lack of direction in the Thai education curriculum (Faikhamta, 2016)

Percentage of students in schools whose principal reported that the school's capacity is hindered to some extent or a lot by lack of qualified teachers								
School type	Socio-economically disadvantaged		Socio-economically advantaged		Rural		Urban	
Year	2003	2012	2003	2012	2003	2012	2003	2012
Qualified mathematics teachers (%)								
OECD average	25.7	19.8	17.1	13.5	22.4	16.6	20.4	13.4
Thailand	46.7	47.8	30.7	47	49.9	65.3	21	45.1
Qualified language-of-assessment teachers (%)								
OECD average	19.1	10.3	12.5	6.5	16.4	8.5	13.6	6.8
Thailand	41.6	48.4	10.2	37.9	43.8	52.6	11	38.1
Qualified science teachers (%)								
OECD average	26.1	19.1	16.1	12.3	19.2	12.8	20.1	13.7
Thailand	38.5	50.1	29.3	44.9	42.7	56.8	17.6	43.9

Figure 3: Percentage of Principals that Reported Lack of Teacher Qualifications Hinder Learning (OECD/UNESCO, 2016)

After evaluation of the Thai Education system, the Ministry of Education (MOE) and the Thai government outlined reforms to improve the Thai Education system and thus the economy following the *Thailand 4.0* ideals. The government has created an Independent Committee for Education Reform to examine and develop the education in Thailand through various studies (Fleischer et al., 2018). Additionally, a survey completed by the MOE determined that teachers' training programs had been ineffective and inefficient, thus various professional development policies have been put in place (Fleischer et al., 2018). Lastly, by 2020, the MOE plans on consolidating 11,000 small rural schools, that hold 120 students or less, in the attempt to reduce the stretch of resources and quality teachers. All phases of the reforms will address the challenges in Thai education and help reduce inequality in Thailand's education (Fleischer et al., 2018).

2.3 Project-Based Learning

In more developed countries, project-based learning in STEM classrooms has created successful learning environments in youth classrooms (Scola et al., 2016). Students learn best when they participate in an activity that captures their interest and gives them an understanding of how science can be used in a real-life setting. Research shows that students' interest and achievement in science improves dramatically when they are able to make connections between what they are learning and the potential uses of the knowledge in the workplace or the world (Basu-Dutt, 2010).

One of the more effective ways to help students make these connections is through a teaching approach called project-based learning (PBL). The Buck Institute for Education has created what they call the "Gold Standard PBL model" which outlines seven essential project

design elements and seven project-based teaching practices (Larmer, 2015). These elements are shown in *Figure 4*.

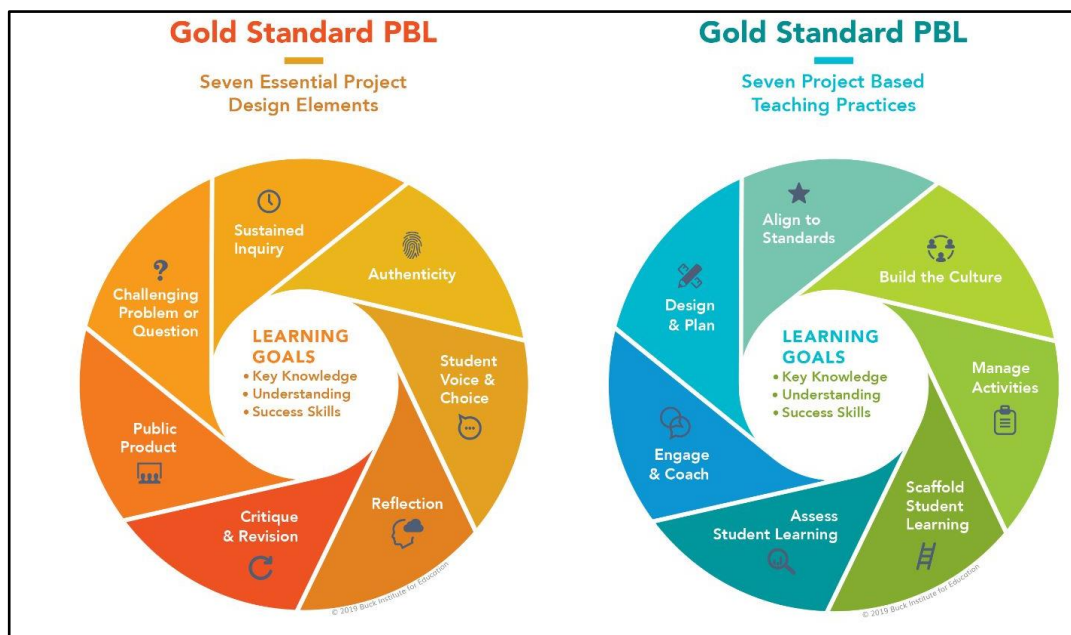


Figure 4: Buck Institute Wheel of Gold Standard PBL Elements (Larmer, J, 2015)

Ideally, project-based learning utilizes the teacher as the facilitator of the project while students work in groups to solve an educational problem in a real world context (Basu-Dutt, 2010). PBL typically includes higher-order questioning, student reflection, problem solving, content integration, and teamwork (Hall et al., 2016). In addition to learning the educational material, students also learn soft skills such as how to think critically, work well with others, and manage themselves effectively (Larmer, 2015). These skills are referred to as “21st century skills”. Part of the *Thailand 4.0* initiative is to provide Thai people with these skills, and project-based learning aids in teaching students these problem-solving techniques. Additionally, after completing an engineering PBL project, students had more confidence in math and science, a higher interest in engineering careers, and more awareness of the nature of engineering (Hall et al., 2016). Implementing PBL in schools can lead to an increase of STEM workers as well as provide all students in the program with soft skills that can be carried over into various careers.

2.4 Small-Scale Chemistry Experiments

Small-scale chemistry experiments provide many educational advantages for students, especially in developing countries. In the 1990s, the first kit that provided all the small-scale equipment to perform an experiment was designed in South Africa by the Research and Development in Mathematics, Science, and Technology Education (RADMASTE). In 1996 UNESCO and International Union for Pure and Applied Chemistry (IUPAC) launched their global micro-science project to promote practical work in counties who did not have the funds for science education beyond theory (UNESCO, 2011). Several developing countries began to

implement small-scale chemistry into their classroom after adapting the kits to fit each of their national curriculums.

The small-scale science experiments offer multiple benefits to students' education. One of these benefits is the safety of the experiments. The "small-scale" promotes safety within classrooms, especially in those without the proper laboratory ventilation and disposal, through the use of small quantities of chemicals. Using less chemicals also decreases the overall cost of materials and the time it takes to prepare solutions (Boyd, 2014). Due to the reduced cost and time, classrooms in developing countries are able to implement hands-on learning into their science curriculum to improve students' engagement and interest in science (UNESCO, 2015).



Students Completing Small-Scale Experiments

A study completed in Ethiopia compares students who use the small-scale chemistry kits created in South Africa to those who solely attend chemistry lectures. Observation in the report shows that all classrooms visited lack basic lab equipment and safety. Therefore, traditional experiments, with large quantities of chemicals would not be safe to complete at this school. The paper concludes that students were more manually and mentally engaged during the small-scale chemistry approach in comparison to their passive listening in their lecture. Students in the small-scale class received higher scores than those who did not complete the experiments. The teachers also report that students gained confidence in class participation through the small-scale approach and allowed timid students to engage regularly (Tefamariam et al., 2014). Overall, the study shows that the Ethiopian students benefit from the integration of hands-on small-scale chemistry experiments while still maintaining a safe learning environment. A similar study completed in Ghana also had successful results of implementing small-scale Chemistry (Handson, 2014).

The use of RADMASTE small-scale chemistry kits continues to expand to Cameroon, Tanzania, Namibia, Sudan and several other countries. UNESCO primary small-scale kit providers are RAMASTE in South Africa, Edulamin UK and Somerset educational. However, each kit's materials and experiment objectives need to be altered to fit each nation's curriculum. Therefore, UNESCO encourages countries to keep developing their own kits to improve their science education to include hands-on learning (UNESCO, 2011).

2.5 The Stakeholders in the DOW Chemistry Classroom

In order to integrate the concept of PBL into more chemistry classrooms, the DOW Thailand Group and the Chemical Society of Thailand (CST) developed a science program that provides students with hands-on small-scale chemistry opportunities to promote science

education. The stakeholders in the DOW Chemistry Classroom can be affected by the results of our project, so it is essential to recognize their contributions to the program and the importance of their respective organizations. These organizations, as well as the National Science Museum (NSM), another organization that is involved in DOW's science programs, is described in further detail in this section.

2.5.1 DOW Thailand Group

The DOW Thailand Group is the largest manufacturer for chemicals in Thailand since 1967. They evolved from a company that solely manufactures chemicals to one that strives to make science a collaborative study and bring greater sustainability to the Thai community. They are now one of the most technologically advanced STEM organizations as well as the most innovative and sustainable chemical company in Thailand ([DOW Thailand Group, 2019a](#)). Partnering with the royal office, they implemented many green incentives and creative science contests in accordance with the *Thailand 4.0* initiative. Every year from 2013 to 2018, the DOW Thailand Group has won Good Governance Awards for Environmental and Safety Excellence ([DOW Thailand Group, 2019b](#)). In addition to their environmental initiatives, the DOW Thailand Group also aims to improve science education in Thailand's youth. To do this, the DOW Thailand Group collaborated with the Chemical Society of Thailand to implement a hands-on science education program, the DOW Chemistry Classroom, in the hopes of continuing the group's mission. ([Tisadondilok, 2017](#)). As a result of these efforts, the Public Affairs Director of the DOW Thailand Group, Poranee Kongamornpunyo, received the 2016 Outstanding Organization in Promoting Science Education in Thailand Award ([Krotintakom et al., 2017](#)).

2.5.2 Chemical Society of Thailand (CST)

Originally, the Chemical Society of Thailand (CST) was a part of the Science Society of Thailand under the Royal Patronage. The president at the time, Dr. Prof. Kamjorn Manu Pichu, collaborated with other Asian countries in 1979 which lead to the creation of the Federation of Asian Chemical Societies (FACS). This federation was the first to promote collaboration of chemistry amongst Asian nations. A year later in 1980, Dr. Prof. Kamjorn Manu Pichu created a branch of the Science Society of Thailand called Chemical Society of Thailand under the Royal Patronage. Currently, there are approximately 2,500 participants in CST ([Chemical Society of Thailand, 2008](#)).

In the years that followed, collaborations between nations continued to grow. In 1981, UNESCO invited chemists from around the globe to a meeting with the purpose of encouraging cooperation by chemists from varying nations ([Chemical Society of Thailand, 2008](#)). After this meeting, the International Organization for Chemical Sciences in Development (IOCD) was founded in 1981 in attempts to promote chemistry and sciences for economic growth in both low-income and developed countries through collaboration between nations ([Krief, 2019](#)). This paved the way for CST to allow the promotion of chemical education and economic development, which aligns with the current *Thailand 4.0* initiative.

Currently, the Chemical Society of Thailand has various goals that revolve around promoting chemistry on an international scale for both national and global benefit. They hope to create a positive image of chemical professions, provide a comprehensive understanding of

chemistry to Thai society, and develop chemical occupations and the chemical industry. Their main objective is to be the center of chemical occupation, industry, and research to create a more developed and successful society Thailand ([Chemical Society of Thailand, 2008](#)).

The Chemical Society of Thailand partnered with the DOW Thailand Group to create the program the DOW Chemistry Classroom. Together, they devised this academic program which concentrates on teaching science teachers throughout Thailand and neighboring countries fundamental chemistry concepts conducted in small-scale techniques. In addition, they have created the DOW-CST Awards, where teachers can showcase their own small-scale experiment innovations ([Chemical Society of Thailand, 2019](#)). The DOW-CST Awards are also sponsored by another renowned science federation in Thailand, the National Science Museum (NSM).

2.5.3 National Science Museum (NSM)

The National Science Museum is located in Pathum Thani Province in Thailand. It was established in 1995 and is operated by the Ministry of Science and Technology. The organization provides science-related extracurricular activities and events to visitors. Some of the activities put on by NSM are the National Science and Technology Fair, various science experiment demonstrations, and a science summer camp ([Pajonporn, 2018](#)).

In addition, the DOW Thailand Group collaborates with the National Science Museum Thailand to support youth chemistry programs. The goal is to promote and encourage interest in science among people, especially youths in Thai society. The NSM believes the DOW Chemistry Classroom program enhances a positive mindset towards science which will lead to a deeper understanding and application of chemistry in the learner's daily life. They believe that increasing interest in science can improve the quality of life of people in Thailand ([Pajonporn, 2018](#)).

2.6 DOW Chemistry Classroom and its Programs

This portion of the report explains the operations of the DOW Chemistry Classroom as well as other related competitions and training. The DOW Chemistry Classroom expands beyond the creation of small-scale experiment kits by offering other programs to expand innovation through competition and collaboration. Specifically, this section will elaborate on two specific programs within the DOW Chemistry classroom entitled DOW-CST Awards and Train the Trainers because our group was able to attend these events to collect data.

2.6.1 DOW Chemistry Classroom

Since 2013, the DOW Chemistry Classroom has aimed to equip school teachers with innovative laboratory techniques that can be brought to life in their classrooms to provide the youth with a safe, interesting, and relatable science education, while producing minimal chemical waste. Their mission is to instill a devotion for science at a young age that can be continued into the adolescent curriculums ([Tisadondilok, 2017](#)). The success of the DOW Chemistry Classroom can assist in the twenty-year *Thailand 4.0* plan by directly impacting science education in Thai youth.

In order to spread these laboratory techniques to schools all over Thailand, the DOW Chemistry Classroom has held training conventions at hotels in Rayong, Thailand since 2013 to train secondary school teachers in basic chemistry laboratory techniques. The conventions aim to educate the teachers on small-scale laboratory techniques that can be easily implemented in a youth classroom. The DOW Chemistry Classroom has chosen to focus on working with teachers because they recognize teachers as the driving force in developing a student's interest and depth of knowledge in a subject, and they want to empower the educators (Tisadondilok, 2017).

The DOW Chemistry Classroom training shows teachers how to complete small-scale experiments using minimal materials that DOW provides to them in contained kits, displayed in *Figure 5*. Once back to their schools, the teachers can purchase the DOW kits and use them to conduct experiments that were taught at the training or they can choose to use the materials in the kits to create their own experiments. The teachers can choose to implement the small-scale experiment in their classroom in whichever way they deem fit.



Figure 5: A DOW Chemistry Kit

The DOW Chemistry Classroom, primarily run by the DOW Thailand group, partners with major organizations that are dedicated to the program's success. They collaborate with the Chemical Society of Thailand (CST) and the National Science Museum (NSM) in order to run the teaching events, and with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) which has made the classroom go global. Since the methods of the DOW Chemistry Classroom are recognized by UNESCO, these teaching methods are also practiced in the Philippines, the United Kingdom, Germany, Austria, Mexico, Japan, China and Cambodia (Chuangchote et al., 2017). These countries are adapting the methods of the DOW Chemistry Classroom because of the wide recognition that the program has attained for its innovative pedagogical strategies.

Through an interview with Dr. Professor Supawan Tantayanon, we found that the DOW Chemistry Classroom program operates in a series of events. First, the conventional DOW Chemistry Classroom training is held which is an introductory training that teaches basic small-scale skills for four different experiments and is open to any high school teacher that is interested. After this training, teachers are encouraged to design their own experiments and submit a video for a small-scale experiment competition, the DOW-CST awards. Ten teachers who have the best small-scale ideas are selected to compete and are then considered to be "role-model teachers" or "outstanding teachers". The role-model teachers are then invited to more intensive training sessions each year, called "Train the Trainers", where they can learn new techniques and network with other teachers. The idea is that the program starts by being open to all teachers then narrows down to an elite few individuals as it progresses.

2.6.2 DOW-CST Awards

To ensure that the implementation of small-scale experiments has effectively enhanced the laboratory performance of high school students, the DOW Thailand Group, CST, and NSM collaborate to hold the DOW-CST Awards competition. The purpose of this competition is to provide students an opportunity to explore their scientific creativity and apply their knowledge to real-life applications. In this contest, the contestants from various schools under DOW design an experiment that follows the competition's theme. The theme of this year's contest was "Waste Management". High school contestants, in groups of four to five were required to design an experiment that was (1) small-scale, (2) different from the provided DOW experiments, (3) consistent with the standard science curriculum, and (4) safe and produced minimal waste (Chemical Society of Thailand, 2017).



Team at DOW-CST Awards

The team that presents an experiment that is understandable and innovative is awarded first place. The winner was also awarded with a trophy by Her Majesty Princess Chulabhorn at the Pure and Applied Chemistry Conference (PACCON) (Chemical Society of Thailand, 2017).

2.6.3 Train the Trainers

Role-model teachers participate in workshops entitled "Train the Trainers" which includes a day of intensive training followed by the Pure and Applied Chemistry International Conference (PACCON). The intensive training allows teachers to collaborate, discuss, and improve on chemistry techniques. This year's event was held at the Mandarin Hotel in Bangkok. On the day of the training, teachers discussed the challenges they faced while implementing small-scale experiments. This experience allows teachers to learn from one another understand how others have overcome obstacles. Teachers in attendance expand on their techniques by learning and completing two additional small-scale experiments, as shown in Figure 6. At the end of the training, teachers return home with two DOW small-scale experiment kits and a large box full of various small-scale lab equipment (blue box in Figure 6). This equipment allows teachers to design their own experiments for future awards.



Collaboration of Teachers at Train the Trainer

Teachers expand on their chemistry techniques at the PACCON event which includes a guest speaker from another country. This presentation from this speaker allows ASEAN teachers to learn chemistry techniques from around the globe. This event allows the role-model teachers to expand on their collaboration, techniques, and professional networking.

2.7 Assessment Methods

When writing survey questions, there are various factors that come into play regarding unintentional bias and word choice. Professor Heilman of Worcester Polytechnic Institute stated that assessing a student's interest in a subject is very difficult. During an interview, he described the challenges of writing survey questions without introducing bias or leading the individual towards a desired response. In response to this difficulty, he suggested consulting experts when writing the questions. Reference [Appendix A2](#) for a detailed report of the interview with Dr. Prof. Heilman.

Our group researched how other science programs implemented around the globe assessed the success of their program, as seen in [Appendix A3](#). Additional educational journals and other studies provided several other theories behind unbiased assessment methods. One of these theories, the social cognitive career theory, is particularly useful in assessing career interest. The social cognitive career theory aims to explain three interrelated aspects of career development: “(1) how basic academic and career interests develop, (2) how educational and career choices are made, and (3) how academic and career success is obtained” (Fouad, 2014). *Figure 6* below details how interest, goals, expectations, and other factors can be used to predict interest using social cognitive career theory (Fouad, 2014).

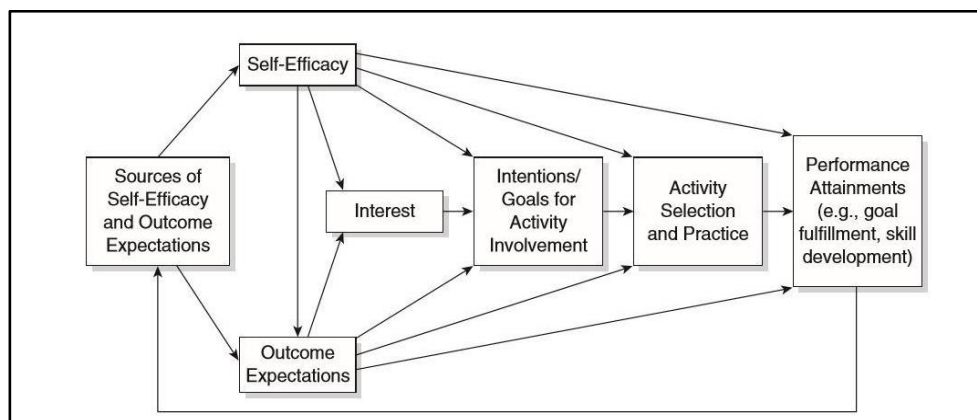


Figure 6: Predicting Interest Development in Social Cognitive Theory (Fouad, 2014)

One of the main portions of the social cognitive career theory, assessing interest, is essential in an individual's career path; as interest in a subject increases, goals and ambitions within that subject develop which overall increases that individual's participation and effort in that subject ([Brown et al., 2017](#)).

Another method of assessment was published in *the Journal of Chemical Education* in 2007, titled Attitude towards the Subject of Chemistry Inventory (ASCI). The ASCI assessment identified three main categories that impact students' interest in chemistry: anxiety, intellectual accessibility, and emotional satisfaction ([Bauer, 2008](#)). Each of these categories were assessed

with four to five contrasting adjectives in each displayed below in *Table 1*. Students were prompted with the statement in the second row of the table to guide their responses and rank their feelings on a scale of one to seven between the two polar adjectives ([Bauer, 2008](#)).

Table 1: ASCI Assessment Method: Contrasting Adjectives to Assess Specific Categories

Anxiety	Intellectual Accessibility	Emotional Satisfaction
During this experiment I felt...	This experiment was...	This experiment was...
Nervous - Calm	Complicated - Simple	Unpleasant- Pleasant
Relaxed - Tense	Confusing - Clear	Uncomfortable - comfortable
Safe - Unsafe	Hard- Easy	Chaotic - Organized
Anxious - Unconcerned	Challenging - Unchallenging	Frustrating - Satisfying
Apprehensive - At ease	Incomprehensible- Comprehensible	--

The ASCI assessment method has been applied to several studies published in *the Journal of Chemical Education*. The report suggested that the survey be implemented in one of two ways, to compare different learning environments or in a pre and post experiment tactic so responses can be compared ([Bauer, 2008](#)). One study completed by Hensen and Barbera in 2019 implemented this assessment method to compare students' interest between virtual experiments and hands-on experiments. This survey method allowed the researchers to understand the learning environments impact on students' perspective towards the subject of chemistry and compare the results to understand which learning method had the greatest impact in attitude ([Hensen, 2019](#)).

2.8 Conclusion

Thailand's current economic and technological standing has been improving, but in order to continue climbing the ranks they are focusing their efforts on improving their STEM education system. Their new economic initiative, *Thailand 4.0*, is helping to guide them towards a more innovative and sustainable economy. The DOW Thailand Group can aid in this initiative by improving the quality of science education through the integration of project-based learning into youth schools.

Other successful programs used project-based learning in both formal and informal education settings to pique student interest in STEM. The greatest difficulty in assessing the success of these various programs was limiting bias and retrieving a large enough sample size. In order to ensure that the DOW Chemistry Classroom is successful in generating a greater interest in science among Thai youth, our team will use our knowledge of successful STEM programs

and their assessment methods to guide our assessment of the DOW Chemistry Classroom and provide suggestions for improvement. In the next chapter, we describe the information we sought and how we obtained the data through various research methods.

Chapter 3: Methodology

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- 3.1 Survey Data to Determine Student Interest in Science
- 3.2 Science Enrollment Data to Determine Student Interest in Science
- 3.3 Evaluate Students' Reaction to Small-Scale Experiments
- 3.4 Evaluate Teachers' Opinions on Implementing Small-Scale Experiments
- 3.5 Provide Recommendations for the DOW Chemistry Classroom
- 3.6 Limitations of Data Collection
- 3.7 Ethical Considerations When Using Surveys

CHAPTER 3: METHODOLOGY

The successful implementation of the DOW Chemistry Classroom could result in great outcomes for the students and the economy of Thailand. In order to assess the success of this program we developed four objectives that analyzed different aspects of the DOW Chemistry Classroom:

1. Determine if the DOW program has led to increased student interest in science
2. Evaluate student's emotional reactions to the small-scale experiments
3. Evaluate if DOW teachers have the desire, skills, and confidence to implement small-scale experiments into their classrooms
4. Provide recommendations for how the DOW Chemistry Classroom could increase student interest in science in the future

To achieve these objectives, our group developed and distributed surveys to both students and teachers, interviewed both students and teachers, and collected enrollment data to identify comparable trends. We attended the DOW-CST awards, [section 2.6.2](#), event at Chamchuri Square, where twenty science teachers previously trained under DOW competed in a small-scale chemistry experiment contest. We continued to collect data through school visits in Bangkok, Prachin Buri, Chachoengsao, and Rayong to observe the experiments and collect various forms of data via survey and group interviews. At the Train the Trainers Conference (see [section 2.6.3](#)), we interviewed conference participants, distributed survey questionnaires, and observed the small-scale experiment lessons. Lastly, since we did not have time to visit every school, DOW provided us with a list of teachers' emails who were trained under the DOW program and surveys were distributed to them. The following table, *Table 2*, outlines which types of information were collected from each location.

Table 2: Data Collection Methods and Locations

	Rayong / Chacheongsao / Prachin Buri/ Bangkok			DOW Email Distribution Of Surveys	DOW-CST Awards	Mandarin Hotel Conference
	No lab	DOW	Full lab			
Teacher Survey	✓	✓	✓	✓	✓	
Teacher (DOW) Survey		✓		✓	✓	✓
Teacher Interviews	✓	✓	✓		✓	✓
Student Interest Survey	✓	✓	✓	✓	✓	
Student Experiment Survey		✓	✓	✓	✓	
Student Group Interview	✓	✓	✓		✓	
Science Enrollment Data	✓	✓	✓	✓		

In this chapter, we will discuss the need for these methods of data collection, and how we completed them. First, we discuss our student assessment plan. Then we discuss how we used student enrollment data to see if more students have pursued science majors since the implementation of the DOW program followed by the experiment assessment plan. We then discuss our teacher assessment plan which assesses how the teachers feel towards completing the small-scale experiments in their classrooms. Lastly, the results from our surveys and interviews were assessed to provide recommendations to the DOW Thailand Group.

3.1 Survey Data to Determine Student Interest in Science

In order to measure if the students' interest in science and technology changed as a result of the DOW Chemistry Classroom, our group distributed surveys and conducted group interviews with high school students (Grade 10-12). We had planned to survey students in three different school types: schools who use the DOW small-scale experiments, schools with no lab facilities, and schools with full-scale laboratories in order to compare if the students who utilized laboratory experiments in their classroom tend to have a greater interest in science in comparison to students who have no labs.

However, after visiting schools we observed that the different schools do not clearly fall into those three categories (no lab, small-scale lab, and full-scale lab). We found that these categories often overlap; there is a wide range of available lab materials, frequency of experiments, and student to teacher ratio amongst varying schools. In addition to comparing DOW small-scale classrooms to schools that do not utilize these experiments, we decided it was important to compare student interest in science with the quality/quantity of their laboratories. To do this, we used a more complex system to categorize our schools. This system is described in further detail in [section 4.1](#). The full surveys that were distributed to students to assess their interest in science can be found in [Appendix B1](#).

The survey consisted of various statements that the students ranked based on how much they related to the statement. For the purpose of scoring and analyzing the survey data, the scale included “strongly disagree” which corresponded to a score of 1, “disagree” corresponded to a score of 2, “neutral” corresponded to a score of 3, “agree” corresponded to a score of 4, and “strongly agree” corresponded to a score of 5.

These questions are meant to measure various aspects of the students’ perspectives of science based on the social cognitive career theory (SCCT), which can be found in detail in [section 2.7](#). Based on this model, our questions targeted various aspects of the student’s views on science such as the student’s confidence to succeed, their personal goals, their expectations, their interest, and their support system. The following *Table 3* lists the statements on the survey as well as the category that each question falls into.

Table 3: Questions to Assess Student Interest in Science

Question #	Social Cognitive Career Theory Aspect	Question: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) & 5 (strongly agree).
Q1	Self-Efficacy	I am able to get a good grade in my science class.
Q2	Self-Efficacy	I am able to complete my science homework.
Q3	Personal Goal	I plan to use science in my future career.
Q4	Personal Goal	I will work hard in my science classes.
Q5	Outcome Expectations	If I do well in science classes, it will help me in my future career.
Q6	Outcome Expectations	My parents would like it if I choose a science career.
Q7	Interest in science	I am interested in careers that use science.
Q8	Interest in science	I like my science class.
Q9	Contextual Support	I know of someone in my family who uses science in their career.
Q10	Personal input	I would feel comfortable talking to people who work in science careers.
Q11	Teacher efficacy	My science instructor explains concepts in a way that I understand
Q12	Teacher efficacy	My teacher makes science fun to learn

Questions 3, 7, and 8 were used to directly assess student interest in science or pursuing a science career. The other questions on the survey were used to assess if there were any outside factors that could influence students’ interest in science. We used these questions to analyze which factors contributed to the student’s interest in science that are unrelated to the DOW

experiments. It was important for us to be aware of these impacting factors such as family influence so we could properly measure the impact of the program without any bias.

We also included questions that are not part of the social cognitive career theory (Q11 and Q12) that asked about student's opinions of their teachers. Since the DOW program trains teachers on how to conduct small-scale experiments in their classrooms, it is important that students benefit from the skills that teachers learn from DOW teacher training. We wanted to be able to assess if there is a correlation between having a good science instructor and being interested in science.

In addition to utilizing survey questionnaires to assess students' interest in learning science, we also conducted small group interviews of approximately five students in middle schools and high schools. These interviews focused on students' personal opinions towards science and allowed us to understand the current situation of their science education and curriculum in Thailand. We asked them questions focused on their perspective on science and whether they enjoyed their small-scale laboratory experiments. The purpose of these interviews was to provide confirmation that the survey data showed the right correlation between students' interest in science and their access to laboratory experiments. We conducted these interviews at the DOW-CST Awards and various schools throughout Thailand. The list of student interview questions can be found in [Appendix B2](#).



Team Conducting Student Interviews

3.2 Science Enrollment Data to Determine Student Interest in Science

We planned to collect statistical data from high schools throughout Thailand because we wanted to find out if the DOW program has led to increased student interest in science. This data included statistics on the number of students that pursued a science major in high school and how many students continued their science education into university. We hoped to see that student enrollment in science increased after the implementation of the DOW program.

Since the DOW program has been running for seven years, we gathered statistics prior to DOW's program and compared these trends with the trends of student enrollment after the DOW Chemistry Classroom initiated its program. We wanted data from the last fifteen years in order to compare the rates of science enrollment after the implementation of the DOW program to the rate before DOW. Comparing these trends within one school will eliminate outside factors that may impact science enrollment. To collect this data, 502 emails were successfully distributed to teachers trained by DOW. In this email, we asked the teachers to forward the enrollment survey (displayed in Appendix D) to the principal of the school. Our hope was that the principal could input a file with the desired data for our analysis.

When the trends of students' enrollment in science majors (in both high school and university) were analyzed, we hoped to see if the implementation of the DOW Chemistry Classroom led to an increase in the number of students that decided to pursue a science education. We compared the enrollment trends of DOW schools against schools that do not use DOW in order to have a baseline to compare to the DOW data. This helped us understand if there was already a general upward trend in science enrollment in all schools since we did not want to falsely attribute this upward trend to DOW. Additionally, we hoped to see a “spike” or general increase in the number of students who pursued science when the DOW program was implemented after accounting for any general trends.

3.3 Evaluate Students' Reaction to Small-Scale Experiments



Students Completing Small-Scale Experiments

We believe the success of the DOW Chemistry Classroom was highly dependent on the experiment's ability to boost students' interest in science through an appealing and interactive learning style. In accordance with our second objective, we gathered data to understand the students' emotional reactions towards the small-scale experiments performed in their classroom. Since the DOW experiments varied among the schools, the questions were general rather than specific to one experiment. The experiment survey questions were distributed to schools that use the DOW small-scale experiments either on site in the previously mentioned school districts or via email distributions from teachers.

This section of the student survey gauged the students' interest in the experiments through an adaptation of the Attitude towards the Subject of Chemistry Inventory (ASCI) assessment, refer to [section 2.7](#). However, the original ASCI tool lacked an area for students to explain their responses and had limitations due to inaccurate translation of adjectives to Thai. Therefore, we adapted the original ASCI survey to better fit our research goal. The original ASCI survey included five pairs of adjectives for each category, but we reduced the survey to one or two adjective pairs to keep the survey concise. The adjective pair “excited and bored” was added to the emotional satisfaction section because we believed this was an important reaction to evaluate for our goal. We also included a short-answer question after specific adjective pairs to obtain reasons for students' answers. This provided feedback for ways to improve the program and emotional satisfaction scores in the future.

Table 4 below illustrates the chosen adjective pairs used to assess each contributing factor along with the starting statements that guided the students' answers ([Hensen, 2019](#)). A complete copy of the survey question can be found in [Appendix B1](#).

Table 4: Contrasting Adjectives to Assess Specific Categories

Anxiety	Intellectual Accessibility	Emotional Satisfaction
During this experiment I felt...	This experiment was...	This experiment was...
Nervous - Calm	Challenging - Unchallenging	Unpleasant - Pleasant
	Incomprehensible - Comprehensible	Boring - Excited

Through this survey we could interpret students' feelings towards the small-scale experiments. The anxiety category showed if the students were comfortable completing the experiments; if the environment created by the experiment caused high anxiety in the students, they most likely would not be interested in continuing with a science education. The intellectual accessibility category portrayed if the experiment was at the correct difficulty level to ensure that students were challenged in an encouraging, rather than discouraging, manner. Lastly, the emotional satisfaction category gave us an understanding of students' emotions created by the experiment; students would be more likely to pursue a science-related career if they were emotionally satisfied by the classroom experiment.

Although the ASCI assessment method was created by experts to ensure the selection of adjectives produced limited bias, there was still the possibility that students provided biased answers created by their surroundings. When analyzing this data, we considered that the students' feelings could be influenced by their teachers and/or their peers, or societal norms. We hoped to capture their true emotions towards the experiments that were not influenced by outside factors. To account for this bias, we asked students "why" they chose their answer, which allowed us to gather an understanding of what caused their emotions towards the experiment.

In addition to the adjective pairs, we also asked questions about students' experience performing the experiments. These questions are formatted similar to the survey style mentioned in objective one: on a five-point scale ranging from strongly disagree to strongly agree. The questions helped us understand if students felt like they learned from the experiment, understood how it can apply to the real world, and if it piqued their interest. If students were interested in the activity, were learning the concepts behind the experiment, and understood its importance in the real world, then the students would likely be more interested in the science field.

3.4 Evaluate Teachers' Opinions on Implementing Small-Scale Experiments

The DOW Chemistry Classroom recognizes teachers as the driving force in a student's educational experience and success. Measuring the success of the DOW Chemistry Classroom can be partially determined through analyzing teachers' confidence in the lessons they teach,

their knowledge of the subject, and if they felt as if they have benefitted from DOW's teacher training.

In order to obtain this data, we provided a confidential survey to teachers that were trained through the DOW Chemistry Classroom and teachers not trained under the DOW Chemistry Classroom. The reason for surveying two contrasting groups of teachers was to compare the data between the two groups and make a correlation between the DOW program and teacher competence. The questions on this survey first covered demographics and personal information such as age, teaching experience, prior teaching education, school district, school name, etc. The questions then moved into more logistical topics, such as their depth of knowledge in the subject, confidence in their teaching ability, and enjoyment in teaching chemistry. These questions were based on a five-point scale, from "strongly disagree" to "strongly agree". The teachers ranked on this scale based on how much they agree with the statement.



Team Conducting Teacher Interviews

Lastly, there were DOW specific questions related to how the teachers felt about the DOW training program. This portion was open ended and reflective, similar to a short answer or essay question. This included what the teachers liked and disliked about the DOW training, and any suggestions or comments they may have. These questions will not be included in the survey for teachers not under DOW. Refer to [Appendix C1](#) for a complete copy of the distributed teacher survey.

Table 5: Survey Questions for DOW Teachers

Personal Information fill in with your personal information	Teacher Efficacy 5 point scale: “strongly agree - strongly disagree”	DOW short answer (SA), 5 point scale “strongly agree - strongly disagree”(5PS)
Age	I have the appropriate resources to complete science experiments.	5PS: The two week DOW training was enough time to learn the lessons being taught.
Gender		5PS: I learned something new from my DOW training.
Languages Spoken	I feel confident incorporating technology into my lesson plans.	5PS: The lessons taught at the DOW conventions are relevant and useful.
School District		5PS: I felt like I could ask questions if needed at the DOW training.
School Name	I have the proper chemistry background to teach my class.	SA: How do you feel about teaching chemistry before versus after DOW training?
Grade Level		SA: Is the DOW training applicable to your classroom?
Classroom Size	I can answer my student's questions clearly and correctly.	SA: How did the students respond to the DOW experiments?
Ventilation Method		SA: What suggestions do you have for the DOW program?
Waste Disposal Method	I am knowledgeable in chemistry.	
Available Technologies		
Previous Personal Education/ Degrees Obtained	I feel comfortable running laboratory experiments in my classroom	
Other Non-formal Programs Used		

These surveys were distributed via email to 1,092 teachers trained under DOW. The email contained links to both the teacher and student surveys and asked teachers to distribute the student survey to ten students. We planned to distribute all the emails to teachers with a two-week deadline. However, certain limitations were faced when attempting to email all teachers on the same date. These limitations are discussed in [section 3.6](#). The purpose of emailing teachers as well as surveying teachers at schools we visited was to obtain a large enough sample size. In person survey distribution was completed during the DOW- CST Awards and school visits. Additional Thai and ASEAN teachers were also surveyed at the Mandarin Hotel conference, where the outstanding DOW teachers learned to become “trainers” of DOW small-scale experiments.

In addition to surveying, we also conducted interviews at a variety of schools and the Mandarin Hotel conference to gather more information on their confidence in implementing experiments into their classrooms. We were interested in learning about the challenges and benefits of using small-scale and full-scale experiments in a classroom. Similar to the surveys, the interviews consisted of questions about resources, student to teacher ratios, and other factors that affect learning. The information from these interviews were unique because it allowed us to ask follow-up questions and gain an in-depth understanding of laboratory experience in Thai high schools and some middle schools. Through these interviews, we were able to build a connection with teachers which allowed us to receive more genuine responses and recommendations to improve the DOW program. The interview questions can be found in Appendix C2.

The answers to the survey questions and the content from the interviews were analyzed to assess the success of the DOW program. The quantitative answers to the questions above can be statistically analyzed and comparisons can be made between different classrooms. Based on the

results, weaknesses can be identified in teachers' experiences with the DOW training and the small-scale experiments, and suggestions can be made to improve the DOW program.

3.5 Provide Recommendations for the DOW Chemistry Classroom

After collecting the survey data and statistical data we described in [sections 3.1](#) through [3.4](#), we analyzed our results to determine ways to improve the DOW Chemistry Classroom. Our surveys were created to identify student interest, the experiment's ability to engage students, and/or the effectiveness of teacher training. After analyzing our data and identifying these weaknesses, recommendations were given, which can be found in [Chapter 5](#).

3.6 Limitations of Data Collection

There were several limitations in our data collection methods. Translating our survey questions from English to Thai was necessary for the Thai students and teachers to fully comprehend the questions. However, it was a challenge because the English words did not always directly translate into Thai while maintaining the same meaning. This was especially problematic in our questions that utilized contrasting adjective pairs (discussed in [section 3.3](#)). This question style is dependent on the meaning of the word so a slight difference could lead to different results.

Another limitation we faced was sample size. We received a list of 1,150 emails of Thai teachers trained by our sponsor, the DOW Thailand Group. We attempted to distribute our surveys to the DOW teachers via email in the hopes of reaching as many schools as possible. However, we could not ensure that a large enough number of teachers would answer the surveys, so we faced some undercoverage bias. Also, since these surveys were optional and we were not randomly selecting our participants, this type of surveying could be categorized as convenience sampling. This is a specific type of non-probability sampling that relies on using members who are conveniently available to participate. This could have resulted in only having teachers with strong feelings towards the program respond to the survey (either teachers who are big advocates for the program or teachers who think it is not effective and will use the surveys as an outlet to complain about the program).

Time was also a limiting factor. We attempted to distribute all of the surveys through email, and the original plan was to set a two-week deadline for the teachers to complete the survey. However, Gmail limited the number of emails we could distribute each day (at a cap of 500 emails per day). As a result, half of the teachers were able to have a full two weeks to complete the survey. The second half of emails were sent out with only a week to complete the surveys, which could have impacted the number of responses. We attempted to send out emails to the entire list our sponsor provided but 105 of those emails failed due to full inboxes or addresses not found.

Another limitation is verifying if the survey answers truly reflected the teachers' opinions. Some of our questions asked about their ability to answer chemistry questions, which they may not have wanted to admit to because of embarrassment. Also, if the teachers did not feel the DOW program was effective, they may be afraid to critique the program.

Studies have shown that when asking participants to self-report their interest in something, they are likely to give a “socially desirable response” (Landrum et al., 2016). Since our survey questions clearly showed that we were trying to gauge their interest in science, it was possible that students gave a statement a higher score because they believed that it was the desired response. When teachers or students were asked about the DOW program, they may have felt obligated to give positive answers about DOW to ensure the program continued to aid them. Similarly, the presence of a DOW representative at schools during our visits could have provided an added pressure. When conducting school visits, some schools were presented with free small-scale lab kits as a thank you for allowing us to come to their school and interview them. The presentation of these free lab kits could have created bias in interview and survey responses as well, potentially swaying the teachers and students to respond positively.

To mitigate the limitations of our study, we collected quantitative enrollment data. However, since we were not able to distribute the enrollment data survey to all of the schools who use DOW, there could be potential undercoverage bias or convenience sampling bias due to the fact that the small sample we received may not be representative of our entire target population. The limited enrollment data that we did receive did not provide the correct categories of information that we required to make accurate claims about the impact of the DOW Chemistry Classroom.

3.7 Ethical Considerations When Using Surveys

Many ethical limitations came into play when constructing and implementing a survey that impacted human subjects. It was essential that each subject taking the survey gave informed consent before completing the survey. This meant that the subject was entirely aware of what the survey entailed and what the data would be used for. The survey could not be mandatory and no subject could be forced into taking the survey. In addition, the questions and methods of surveying could in no way harm the subjects. They could not be swayed into answering the questions in a particular manner or be treated differently based on their answers.

Students who completed our survey were informed that their participation was voluntary and that they do not have to answer all questions. They reflected on their interests, future career choices, and experience in the classroom. If the students had not yet begun to consider their future career paths or already have a sense of anxiety around school or careers, our survey could have caused them to panic about their future success or make them question their abilities to succeed.

Teachers who completed our survey had to reflect on their teaching abilities and experience with the DOW Chemistry Classroom. These surveys were confidential and anonymous, but it was still possible that teachers hesitated to self-report their weakness or critique the DOW program. We ensured complete confidentiality in these surveys in order to obtain honest responses from the teachers. Teachers answered questions about their confidence in their own teaching abilities and their ability to answer questions from their students. This survey may have caused the teacher to begin to doubt his/her own abilities and possibly lead to a change in their teaching style.

With the data collected from the surveys, our group could suggest several implementations that would positively benefit the teachers and students participating in the

surveys. Based on student feedback from the surveys, our suggestions could alter the faults in the DOW experiments and could help students have a more positive outlook on science education. Teacher feedback could help us devise ways the teachers implement the DOW experiments in a more efficient manner and provide potential improvements to the DOW teacher training. However, our recommendations for the DOW Chemistry Classroom would be based on data collected from a wide range of students and teachers with different perspectives. Therefore, our recommendation may not satisfy all participants.

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Chapter 4: Results and Analysis

CHAPTER 4: RESULTS AND ANALYSIS

This chapter elaborates on the results from the student and teacher surveys and interviews. It begins with a description of how we categorized our data to set a control group. We then discuss our analysis and findings for our first objective: determining if the DOW Chemistry Classroom has led to an increase in student interest in science. Next, the results section shows the effectiveness of small-scale experiments. Lastly, we will detail teachers' thoughts on the benefits and challenges of implementing small-scale experiments.

4.1 Categorizing Data for Analysis

To complete our goal of assessing how the DOW Chemistry Classroom has influenced Thai youth's interest in science, we wanted to compare students who do DOW small-scale experiments to a control group. We wanted to compare three categories of high schools: schools that do not use labs, schools that use small-scale labs, and schools that use full-scale labs. "No lab" and "full-scale lab" schools were originally considered non-DOW, and these schools were intended to be used as a control group. After visiting schools to collect data, we discovered that these boundaries were not as clearly defined. For the purpose of analysis, we created our own system to categorize these schools; we decided to use lab frequency, quality of lab materials, and number of students per lab group, to categorize the schools. Therefore, any data used for analysis was from schools we visited.

DOW versus non-DOW

To define a school as a "DOW" school, we decided that the students must use small-scale experiments more than once a semester. Students who did not do small-scale experiments at all or performed them at most once a semester were considered to be "non-DOW". It was our opinion that only performing labs once or twice a year would not result in a recognizable impact compared to someone who did not use the experiments at all.

Lab Quality Score

We initially wanted to compare no lab, small-scale lab, and full lab data to analyze if the presence or type of a lab had a difference on student interest in science. As a replacement for these categories we used a grading system to create a "lab quality score" to see if the quality and quantity of student's experiments led to higher interest in science. Three factors were used to determine a lab quality score: frequency of experiments, lab group size, and quality of lab resources. We gave each school a score of one through five for each of these categories and then averaged the three scores to create an overall lab quality score. The criteria for what qualifies a one through a five can be found in [Appendix E](#).

4.2 Correlations Between Various Factors and Student Interest in Science

Our first objective was to gather various types of data to determine if the DOW program has led to increased student interest in science. To do this our group used a student survey and group interviews.

4.2.1 Analysis of Student Interest Surveys

The student survey was designed for students to express their interest in science. It was given to students who use small-scale experiments, full-scale experiments, and a mix of both. We analyzed how interest varies between these categories and how outside factors impact interest in science.

DOW schools have a greater interest in science than non-DOW schools.

We compared the interest of DOW students to the control group, non-DOW students. We used the responses to three questions to assess student interest:

1. “I plan to use science in my future career”
2. “I am interested in careers that use science”
3. “I enjoy my science class”

We asked students to rank their feelings towards the statements above from strongly disagree (1) to strongly agree (5). The distributions of answers to these questions are seen below in *Figure 6*.

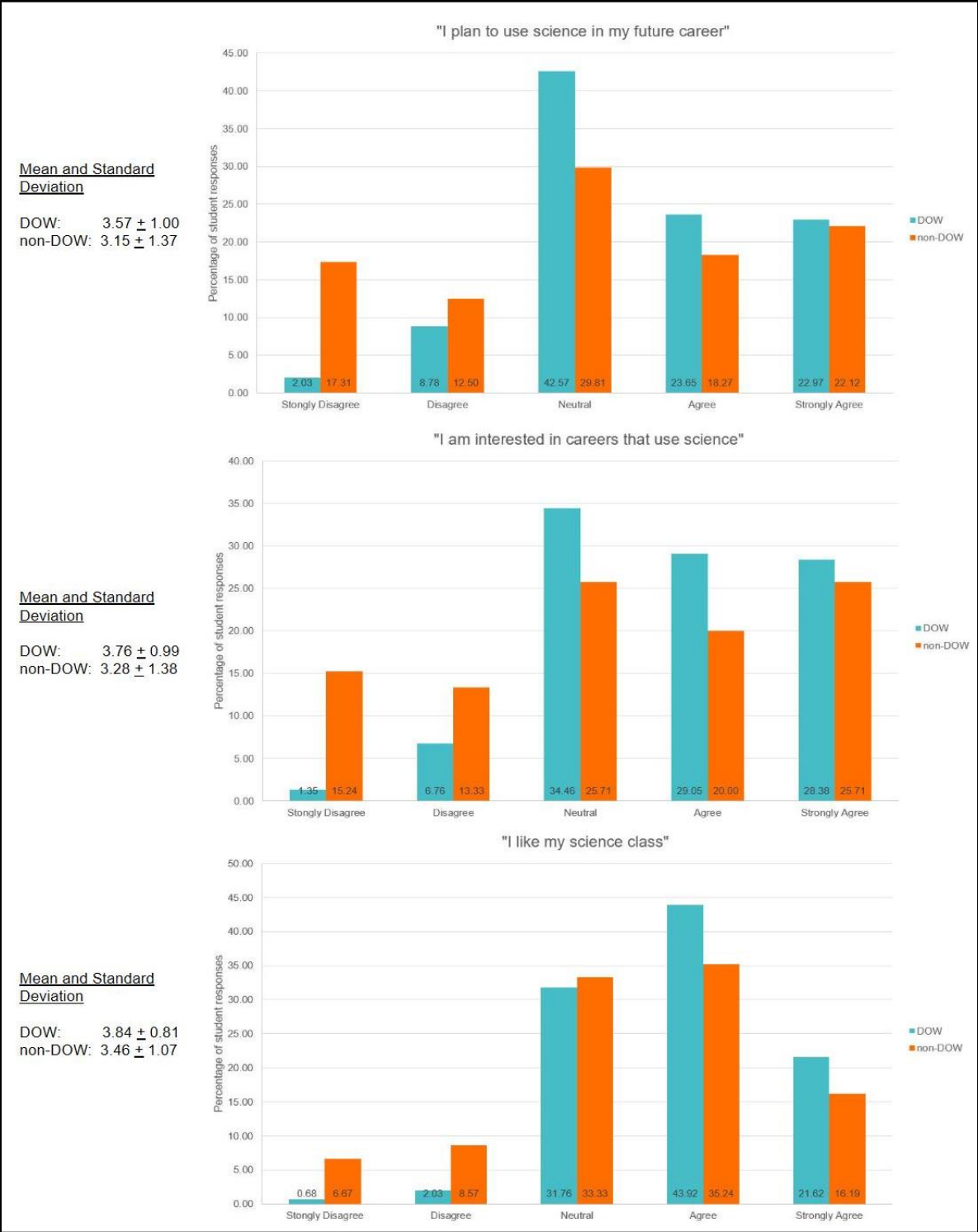


Figure 7: Comparing Interest in Science Between DOW and Non-DOW

We sampled 105 students from four different “non-DOW” schools and 148 students from four different DOW schools. This sample size consisted of students who completed the survey and attended schools that we visited.

As displayed in *Figure 7*, the DOW students generally answered agree or strongly agree more than non-DOW students. A [two-sample t-test](#) proved the difference in means to be statistically significant between all three questions at a significance level of 0.05. We chose this boundary since 5% is a common threshold for most significance testing ([StatTrek, 2020](#)). We found it is greater than 99% likely that the average interest in science in DOW students is higher than that of non-DOW students.

There are some limitations that may have caused this difference in means. Out of the four “non-DOW” schools, one of the schools we visited was a school for aspiring monks so most of these students responded that they had very little interest in science careers. The students from the monk school accounted for 31% of our non-DOW population, which may have lowered the average scores for non-DOW schools.

Schools with greater lab quality have a greater interest in science.

We also assessed if lab quality (having labs more frequently, having quality materials, and doing labs in smaller groups) affected interest in science. We compared responses to three science interest questions to a school’s lab quality score (the calculation of a lab quality score can be found in [section 4.1](#)).

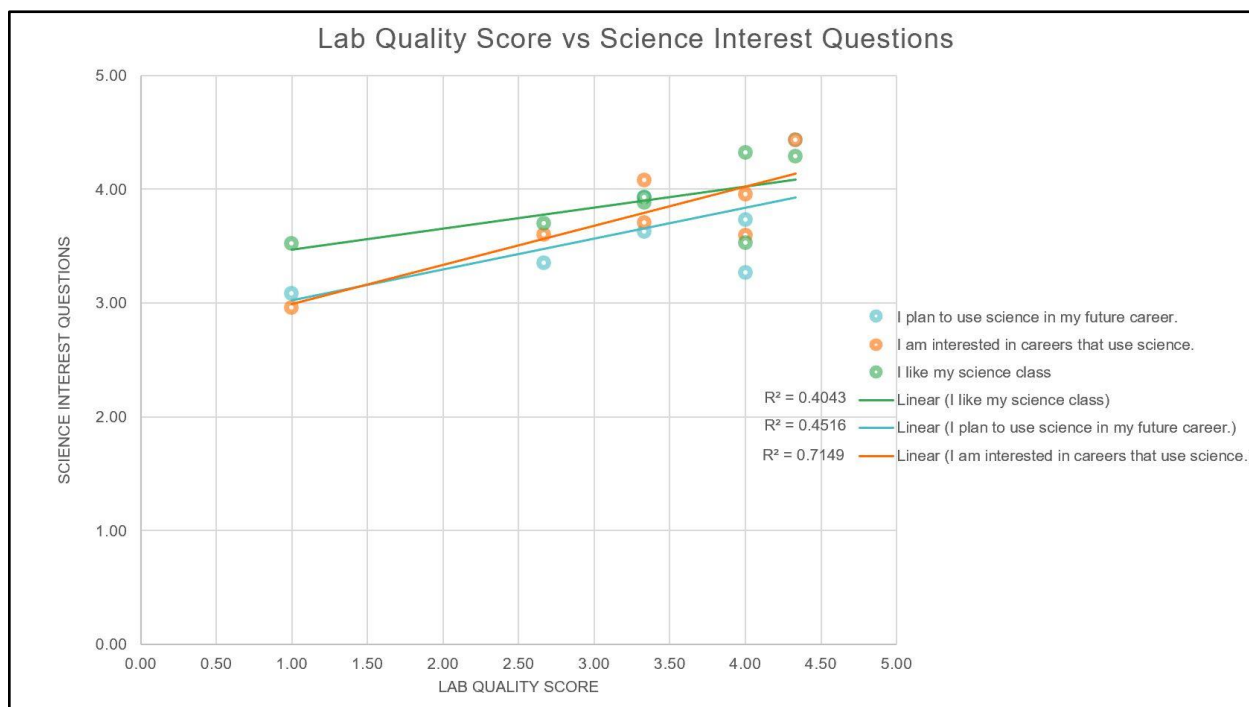


Figure 8: Lab Quality Score vs Science Interest Questions

The [r values](#) for our trend lines vary between questions with scores of 0.636, 0.672, and 0.846. The first two values are not as close to one as preferred, but there is still evidence of a correlation. The last value shows a decently strong positive correlation between the variables.

DOW schools have a higher lab quality

We found that DOW schools tended to have a higher lab quality score. The average lab quality score for non-DOW schools was 2.17 and DOW schools was 3.92. One of the following three cases could be the cause of the relationship between DOW schools and high lab quality.

1. DOW schools have a higher lab quality because they are DOW schools

It is likely that the implementation of small-scale chemistry could lead to a higher lab quality score if implemented properly. The experiments are easier to set up which could increase lab frequency. Small-scale experiments are cheaper than full-lab materials so more kits can lessen the lab group size and increase the lab materials score. If our observations are true, DOW small-scale chemistry could lead to higher lab quality. However, it is important to note that this model implies that the schools' budget is big enough to buy an appropriate number of kits.

2. Lab quality is the driving factor behind student interest

It is possible that the success of the small-scale experiments heavily relies on a school's budget. Some "DOW" schools do not have the budget to provide enough materials per student. This would result in the school having a low lab quality and likely having a low interest score. Our research into project-based learning has shown that when students have more hands-on project experience with a topic, they tend to have more interest ([Basu-Dutt, 2010](#)). It could be this hands-on experience that is driving student interest.

3. We took a biased sample of schools and only surveyed high quality DOW schools and low-quality non-DOW schools

This implies that student interest is dependent on lab quality and that our sample of DOW schools was of very high quality. All the "DOW" schools we visited were part of DOW's "role-model schools" and are considered to be the most successful of all schools that use the DOW small-scale experiments. Since these schools were highly involved in the DOW program, it was easier for DOW to arrange our visit with them, but this could have led to the collection of biased data. They had teachers who were highly trained, had won awards, and had participated in the DOW-CST awards. Schools who won the DOW-CST awards were also granted prize money which they could use to buy more materials for their science program. Therefore, the higher lab quality scores could be due to their success in the DOW program.

We cannot form distinct conclusions linking the DOW program to lab quality. We cannot statistically analyze these correlations, but we can claim that we visited high quality schools and considered these to be "DOW". Although we have found statistical correlations that "DOW" schools tend to have great lab quality, we cannot be sure whether it is the small-scale experiments that lead to their interest, but we have found statistical correlations between both.

Parents have a large impact on students’ career decisions

To assess some confounding variables, we compared the answers to two of our survey questions: “My parents would like it if I choose a science career” and “I plan to use science in my future career”. We used all 313 survey responses from both DOW and non-DOW schools to analyze this factor.

		“I plan to use science in my future career”				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
“My parents would like it if I chose a career in science”	Strongly Disagree	15	6	3	0	2
	Disagree	5	16	18	4	1
	Neutral	4	17	63	20	13
	Agree	3	1	23	21	22
	Strongly Agree	2	4	9	19	22

Figure 9: Parent Influence Chart

A [chi-square test of independence](#) showed a very strong correlation with a p-value of 1.47e-26, which justifies a strong correlation between the two variables.

Self-confidence has an impact on students’ career decisions

We compared the questions “I am able to get a good grade in my science class” and “I plan to use science in my future career” to see if a student’s belief in their abilities was related to their career plans. The chi-square test for independence gave a p-value of 5.51e-10, which justifies a strong correlation between the two variables.

Teachers have an impact on students’ career decisions

We compared the questions “My teacher makes science fun to learn” and “I plan to use science in my future career” to see if the teachers’ abilities to make science engaging for students related to students’ career plans. The chi-square test for independence gave a p-value of 0.0156, which justifies a correlation between the two variables.

4.2.2 Trends in Science Enrollment Data

The student enrollment data survey was sent out via email to 502 teachers. We had planned to send these emails to school principals since they likely have the enrollment data, however we were only able to obtain email addresses for DOW teachers. We asked the teachers

to forward the enrollment survey to the appropriate contact, but many schools did not have this information readily available to distribute to us. We believe that because we did not have direct access to people with access to the data, this was the cause of not receiving any enrollment data. This would have been useful for our group to analyze data without any bias. We would have been able to see if the implementation of the program actually leads to an increase in students pursuing science majors.

We did ask teachers in their interviews if they had noticed more students pursuing science majors and they noted that they thought small-scale chemistry did not have a direct impact on students' career decisions. They believed that outside factors such as job openings and parent influence had a larger impact. Based on these observations, it is possible that we may not have seen any difference in science enrollment since the implementation of DOW.

4.2.3 Student Interviews Regarding Interest in Science

The group interviews were conducted in groups of about five students at each of the schools we visited; a full list of student interview questions can be found in appendix B2. The students' interview responses were collected from those who use small-scale experiments, full-scale experiments and a mix of both in grades seven through twelve. These interviews mostly reflected our survey results but also provided us with additional information which shows the external factors that influence a student's career choice.



Student Interviews During School Visit

We observed common statements for why students chose to study science. The answers were typically because of hands-on experience or parental influence. Some students reported that they wanted to pursue arts, but their parents wanted them to pursue a science major. Some students chose to do a science major in high school because they thought it would give them a variety of options for careers in the future. Many students specifically mentioned they were interested in pursuing careers in medicine. On the contrary, the main reason that students were not interested in chemistry was the difficulty of the subject.

We also asked BSAC students from Chulalongkorn University why they decided to pursue a major in chemistry to compare the answers. A few students reported that they chose to study chemistry in university because they had a family business they planned to work at upon graduation. Other students reported that they chose to study chemistry because chemistry was their favorite science and they thought it was easier than physics or biology. One student reported that she enjoyed the chemistry in the show "Breaking Bad" and that had inspired her to pursue a chemistry major in university.

4.2.4 Summary of Changes in Student Interest

We were able to draw conclusions from our student interest survey data:

1. Students in DOW schools have a greater interest in science than students in non-DOW schools.
2. Schools with greater lab quality have greater student interest in science.
3. DOW schools have a higher lab quality
4. Parents have a large impact on students' career decisions
5. Self-confidence has an impact on students' career decisions

We believe that schools who have successfully implemented the DOW program have a higher lab quality and those students are more likely to enjoy science or want to pursue a science career. We see the DOW program as a good way for schools with limited budgets to improve their lab quality and improve student interest in science.

4.3 Effectiveness of Small-Scale Experiments

Our second project objective focused on evaluating students' emotional reactions to the small-scale experiments. The survey and interview questions asked students about their most recent experiments, and how they felt about these experiments. The results are discussed in the sections below.

4.3.1 Analysis of Student Experiment Surveys

We first analyzed the responses to the adjective pair questions, which asked students to rank their feelings towards the experiments. We reviewed the number of responses, mean, standard deviation, and percentage of students who answered agree or strongly agree (A/SA); these are seen below in *Table 6*.

Table 6: Results for Adjective Pairs

Adjective Pair	N	Mean	StdDev	% A/SA
Nervous (1) - Calm (5)	248	4.00	0.84	73.7 %
Incomprehensive (1) - Comprehensive (5)	248	4.14	0.80	83.5 %
Unpleasant (1) - Pleasant (5)	248	4.37	0.83	83.5 %
Bored (1) - Excited (5)	250	4.28	0.82	83.2 %

We also asked the students why they gave the answers they did for these questions. Students responded that small-scale chemistry makes their science class very interesting, particularly giving them a lot of anticipation of what will happen when a reaction starts. Many students answered that they liked the experiments because their teachers made them fun to complete.

We also asked the students to give a score for the adjective pair “Unchallenging to Challenging”. We analyzed this pair separately from the others since, meaning that in this case the desirable answer is not a score of five. It is important that students are challenged so that they are engaged while learning but are not too challenged that they feel defeated by the difficulty. Therefore, we thought that an ideal response would be a score of four and found that most students (44%) reported this score. The rest of the responses were mostly one below or one above four; 20% students scored a three and 30% scored a five.

When asked why the experiment was challenging or unchallenging, most answered that they thought it was challenging because they were unable to predict the outcome of the experiment which made them excited for the result. They enjoyed the challenge and believed that their inability to predict the outcome helped them learn.

4.3.2 Student Interviews Regarding Experiments

The number of students interviewed was approximately 100, with about five students in a group per interview. They reported that small-scale experiments provided them opportunities to perform hands-on experiments more frequently, which allowed them to observe chemical reactions and deeply understand scientific concepts. They also said small-scale experiments are beneficial because they require minimal time and chemicals. On the other hand, some reported that the conventional full lab is also necessary. In some experiments, such as titrations, conventional laboratory equipment enables students to examine chemical reactions more precisely as well as study how they are handled, which could be advantageous for some groups of students who are preparing to apply for a science major in university.



Team Conducting Student Interviews

Some students are not influenced by the small-scale experiments because there is a specific set of instructions to follow, and sometimes they simply record the outcome as told by the instructor. During our visit to non-DOW schools, students wanted to perform more hands-on experiments since they rarely receive the opportunity due to lack of funding and insufficient time.

4.3.3 Summary of Findings Regarding Small-Scale Experiments

In general, we found that students enjoy the small-scale experiments because they are excited to see the results that appear in minimal time and because their teachers made the experiments fun. Most students found the experiments challenging, but not too challenging that they were discouraged. They enjoyed the challenge of not always being able to predict the results. The quick set-up and cleanup was another aspect that the students enjoyed because it allowed them to do the experiments more often. Most students who were fortunate enough to do both full and small-scale labs preferred to do full-scale because it provides hands-on experience with instruments and reactions that they would perform in their university or career.

4.4 Effects of the DOW Chemistry Classroom on Teachers

Our third objective focused on teachers who use the DOW small-scale experiments. We surveyed and interviewed teachers to determine if they desired to use the small-scale experiments, how confident they felt in their abilities to complete them, and their feelings towards these experiments. We also gathered information on how teachers felt about their DOW training, and how the training program can be improved.

4.4.1 Teacher Surveys

Our teacher survey received a total of 92 responses. We had planned to compare responses between non-DOW and DOW teachers, however we only had 10 responses that answered they do not use DOW in their classroom. We decided this was too small of a sample size to compare to 82 DOW teachers, so we excluded their answers and only analyzed averages for the DOW teachers.

DOW teachers are confident in their teaching skills

On average, we found high responses to questions under the “teaching confidence” category. We reviewed the number of responses, mean, standard deviation, and percentage of teachers who answered agree or strongly agree (A/SA) for questions regarding resources, skills, and confidence; these are seen below in *Table 6*.

Table 7: Teachers' Confidence Responses

Statement Given	N	Mean	StdDev	% A/SA
I have the appropriate resources for teaching	82	3.23	1.05	46 %
I feel confident incorporating technology into my lesson plans	82	3.57	1.14	62 %
I can answer my students' questions clearly and correctly	81	3.84	1.13	72 %
I am knowledgeable in chemistry	81	3.62	1.16	67 %
I have strong teaching skills	81	3.70	1.05	70 %
I have the proper chemistry background to teach my class	81	3.80	1.13	75 %
I feel comfortable running laboratory experiments in my classroom	81	3.74	1.20	69 %

It seems that even though many teachers felt they were lacking some resources, they still had confidence in their teaching abilities.

Teachers think the DOW training is effective

We also asked teachers questions regarding their experiences with the DOW training program, as seen in *Table 8* below.

Table 8: Teachers' DOW Experience Responses

Statement Given	N	Mean	StdDev	% A/SA
The training was enough time to learn the lessons being taught	81	3.74	0.91	69 %
I learned something new from my DOW training	81	4.30	0.94	88 %
The lessons being taught at the DOW training are relevant and useful	81	4.27	0.91	90 %
I felt like I could ask questions if needed at the DOW training	80	4.00	0.91	80 %
I was able to apply the small-scale chemistry lessons to my classroom	82	4.13	0.94	85 %
The small-scale experiments are cost-effective	81	3.94	0.86	77 %

Most teachers agreed that the lessons were relevant and useful and that they were able to take the skills they learned and apply them to their classroom.

4.4.2 Teacher Interviews

Small-scale experiments are easier to implement than full-scale

During interviews, most teachers noted that they prefer to use small-scale chemistry since it required less time for them to set up and cleanup. Since all instruments were already in the DOW kit, it was easy enough for students to set up on their own and teachers only had to prepare the solutions. Several teachers claimed another benefit of small-scale experiments was that the equipment costs less than full-scale equipment.



Advanced Training at Train the Trainers

Teachers prefer to use both small-scale and full-scale

Out of the eight schools visited, most of the teachers said they used both small-scale and full-scale laboratories because the standard science curriculum in Thailand, the IPST, requires full-size laboratory experiments for science class. Therefore, the science teachers could not fully replace full-size experiments with small-scale. Most teachers chose to utilize both types of lab depending on skills required for a given science topic: topics that require chemical observation for conceptual understanding in terms of qualitative analysis can be done through small-scale chemistry, while topics that consisted of technical skills, or quantitative analysis, require full-size experiment for completion.

Small-scale experiments capture students' attention

Additionally, many teachers claimed that it was easier to retain student's concentration when small-scale experiments were implemented in the classroom versus full-scale. Their students had more opportunities to complete the labs because small-scale experiments could be implemented into the classroom more frequently due to lower price and less time constraints. Another benefit noted by the teachers was students enjoyed small-scale experiments because of the "less threatening" size and the shorter time to see results.

Teachers struggled to adapt small-scale experiments to their classrooms

However, some teachers faced challenges when they implemented small-scale chemistry in their science class. One of the biggest challenges was coming up with new small-scale experiments that related to the curriculum. Most DOW teachers requested that the DOW program come up with more small-scale experiment kits that fit better into the science curriculum.

4.4.3 Summary of Teacher's Perception of the DOW Chemistry Classroom

Table 9 below displays a summary of the data gathered from teachers through the surveys and interviews.

Table 9: Advantages and Disadvantages of the DOW Chemistry Classroom

<i>Advantages</i>	<i>Disadvantages</i>
Time-efficient <ul style="list-style-type: none"> - Require small chemical quantities - Faster reaction - Approximately 30 min to complete the whole experiment 	Doesn't perfectly fit the curriculum <ul style="list-style-type: none"> - Small-scale chemistry has not been accepted by the IPST curriculum, still required to complete full-scale - Small-scale experiments do not always fit IPST curriculum without adaptation
Cost-effective <ul style="list-style-type: none"> - Lab kits are cheap compared to full-scale lab equipment - Small-scale equipment is reusable - Small-scale experiments do not require an 	Lack of technical skills <ul style="list-style-type: none"> - Small-scale chemistry laboratory does not focus on full-scale laboratory skills, which is essential for university laboratory classes

actual laboratory to conduct	
Reduces chemical waste <ul style="list-style-type: none"> - Small-scale experiments produce little chemical waste - Safer to complete in the classroom due to smaller quantities of chemicals 	Teachers face challenges coming up with new experiment topics <ul style="list-style-type: none"> - Teachers have to come up with small-scale experiments on their own to fit the curriculum but do not have enough knowledge to create them
Promotes student interest <ul style="list-style-type: none"> - Reduced cost & time allows for more experiments 	Lack of lab kits & diversity in kits <ul style="list-style-type: none"> - Limited topics covered by the DOWCC, would like to see new topics covered by SSC - Low cost but still unaffordable in some schools

4.5 Chapter Summary

Overall, we found that DOW small-scale experiments have the largest impact in under-funded schools because those are the schools that are not fortunate to have full-scale lab equipment. However, we found that the majority of DOW training and resources are allocated to the “outstanding” schools which allows these schools to have higher scores in student interest in science due to the amount of teacher training, higher lab quality, and larger quantity of resources.

We also found that the DOW small-scale experiments provide schools without proper laboratory equipment the opportunity to get hands-on laboratory experience via small-scale techniques. Without the small-scale kits, the students would have no laboratory experience due to a lack of full-scale equipment, time, and resources. On the contrary, many schools that do have the time and resources to implement full-scale laboratories depend less on the small-scale techniques because the full-scale experiments provide experience with instruments that would more likely be used in future education. The students enjoyed the challenge of the experiments and were often excited by the results.

Teachers in general liked the low cost and decreased set up and cleanup time of the small-scale experiments. However, they wish they had an easier way to adapt small-scale kits to fit the curriculum and that the kits could cover multiple different subject areas.

Chapter 5: Recommendations

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5.1 Recommendations for the Future of the Program

5.2 Recommendations for Follow-Up Study



CHAPTER 5: RECOMMENDATIONS

This chapter discusses recommendations and improvements for the future of the program through small-scale experiments, training and assistance for teachers, and new programs or events. We also provide recommendations for a follow-up study.

5.1 Recommendations for the Future of the Program

The following section identifies three key areas for the DOW Thailand Group to improve the program. The recommendations were focused on three categories: small-scale experiments, teacher training and assistance, and new events to expand the program.

5.1.1 Recommendations for Small-Scale Experiments

1. Creation of an experiment handbook and tutorial videos

Teachers are taught the basics of some experiments at DOW-organized training sessions, however, the specific experiment taught may not be appropriate for the grade level of the teacher's class. Even if the experiments do fit the teacher's curriculum, some teachers reported they often forget details of the experiments after the short one-day training session.

The creation of a handbook and YouTube tutorial videos with a variety of experimental procedures would ensure that the experiments can be successfully implemented in the classroom. They could use the handbook to browse different types of experiments and use the YouTube videos to refresh their memory on how to set up and run them. This would greatly benefit teachers who do not have much support at their school and struggle to design new experiments with the given materials. The handbook could be produced digitally, but this could limit the number of teachers who could regularly access the procedures. Therefore, both a digital and physical copy of a guidebook would be valuable.

Several other organizations have produced digital databases for teachers to access to help them apply small-scale chemistry into the classroom. For example, the Royal Society of Chemistry has a published collection of over 60 small-scale chemistry experiments with teacher guidelines ([Royal Society of Chemistry, 2009](#)). Additional teacher guidance can also be found on the UNESCO website which includes both teaching and learning material for small-scale chemistry I ([UNESCO, 2006](#)). Ideally, the creation of an original DOW Chemistry Classroom handbook on specific experiments that could be completed with each kit would be ideal to improve the program. However, if resources cannot be allocated towards this creation, teachers using this program should be made aware of resources that exist online that could enhance their small-scale chemistry teaching.

2. Adapt the experiments for primary schools

Many teachers we spoke to suggested that the small-scale experiments be adjusted for primary school students. This would allow an earlier exposure to chemistry experiments which would hopefully lead into a prolonged interest in science carried into secondary school and university. The small-scale kits would have to be adapted to fit into the IPST primary school

curriculum, and there would have to be separate trainings for primary school teachers. However, some of the current DOW trained teachers suggested a volunteer program where teachers can go to underprivileged schools to teach the small-scale experiments (discussed in detail in [section 5.1.3](#)); this idea could be adapted for the DOW secondary school teachers to help train primary school teachers.

5.1.2 Recommendations for Teacher Training and Assistance

1. Creation of a teacher networking platform

The creation of a networking platform for all teachers trained by DOW, such as a Facebook or LINE group, would be beneficial to enhance the teachers' collaboration beyond the training sessions. The group would allow teachers to share experiments, challenges and successes with other teachers at any time rather than only at trainings conducted by DOW. Teachers would be able to constantly challenge and learn from one another. Additionally, all teachers trained by the DOW Chemistry Classroom could benefit from collaboration rather than just the selected "role-model teachers" who consistently attend workshops. This would especially benefit the teachers that are the only science teachers at their school and allow them to develop professionally from a community of science teachers with whom they can ask questions and collaborate.

2. Increase opportunities for non-outstanding teachers

Upon finding that the DOW Chemistry Classroom holds follow-up competitions and trainings for the outstanding "role-model" teachers, we suggest that there are subsequent trainings for all teachers, especially the teachers that are not considered "outstanding". These are the teachers that would benefit the most from follow-up trainings since they struggle the most to design their own experiments.

3. Better communication between DOW and teachers

To avoid teachers losing contact with DOW once leaving the trainings, DOW could potentially work on sending out more emails or using LINE to more consistently keep in contact with the teachers who use the program. The teachers would more regularly be given updates on new training programs and new experiments.

4. Increase advertisement for the DOW Chemistry Classroom

The DOW Chemistry Classroom could develop their advertising techniques to expand the number of teachers and schools that use the DOW program. They should target those who benefit from the low-cost small-scale experiments with an increase in advertisement to these schools via LINE or Facebook.

5.1.3 Recommendations for New Programs and Events

1. Include students and parents

Since [our data](#) shows a ~100% correlation between parent influence and career choice, it could be extremely beneficial for DOW to organize an event that includes parents in their child's

science education. Similar to a DOW training program, DOW could have a science fair where parents can bring their children to gain some hands-on experience and see demonstrations of relatable small-scale experiments. Possibly, this could be a showcase of the outstanding teachers' small-scale ideas (similar to [DOW-CST awards](#)) or it could be run by DOW staff entirely.

2. Create a volunteer program

Several teachers suggested creating a volunteer opportunity for the teachers trained by DOW to visit schools who lack lab quality and a strong science education. The “role -model” teachers have seen the benefits of small-scale chemistry and believe schools with less access to resources could benefit from this program if given the opportunity. As a result, some teachers would be willing to go teach schools about the experiments. This would expand the program in Thailand and allow more teachers to benefit from the program.

3. Make a monthly competition and newsletter

If a Facebook group were to be created as mentioned in [section 5.1.2](#), a monthly update or newsletter could be sent out in this group to keep the teachers engaged in the experiments. This newsletter could include new experiments, new resources, and a competition; at the beginning of each month, teachers could submit a novel experiment, apparatus, or idea to DOW and the winner could be announced at the end of every month in the newsletter. A competition and a newsletter would keep teachers motivated about new ways to improve the experiments and would provide a widespread benefit to all involved.

4. Provide scholarship for funding lab kits

Many DOW teachers that teach in under-funded schools must pay on their own to buy small-scale lab equipment for their class without getting financial support from their school since SSCL is not part of the curriculum. This leads to a small number of kits being used by a large group of students. We recommend that DOW could start a scholarship program that gives out funding to under-funded teachers for new lab materials. Teachers who want to apply for scholarship funding could submit an application demonstrating their financial need and how they utilize the small-scale labs in their classroom.

5.2 Recommendations for Follow-Up Study

A follow-up study is recommended to obtain additional data that we were unable to collect due to time limitations. Further research could support our findings and provide new information that would benefit the DOW Chemistry Classroom in the future.

1. Expand the sample size and diversity of surveyed DOW schools

It would be beneficial to assess a larger and more diverse sample size of schools which implement the DOW small-scale experiments into their classroom. Due to the limited time constraints, only a small portion of schools could be surveyed. In addition, several of these schools were “role-model” schools who are very active in the program. Therefore, it would be beneficial to expand on the variety of the schools assessed to ensure the conclusion from the data is accurate of the whole program and not just those who are successful.

2. Expand the sample size to non-DOW schools

Due to time constraints, examination periods, and limited access to non-DOW schools, we found it difficult to collect data from non-DOW schools. However, we believe it would be beneficial to collect science interest data from schools that have not participated in the DOW Chemistry Classroom small-scale experiments and have only performed full-scale experiments or theoretical science class. The interest data collected from the variety of schools could be compared to the small-scale data. This would allow a thorough assessment of the program's success in science education.

3. Collect enrollment data for science majors

Collecting enrollment data would be beneficial to identify the success of the DOW Chemistry Classroom. The statistics on the number of students that pursue a science major in high school and how many students continued their science education in university since the creation of the program could be used to assess students' interest in science due to the implementation of small-scale chemistry. It would be ideal to get at least 8 years of enrollment data from both DOW and non-DOW schools to successfully identify a trend in science interest influenced by DOW.

Chapter 6: The National Impact of Small-Scale Chemistry



CHAPTER 6: THE NATIONAL IMPACT OF SMALL-SCALE CHEMISTRY

After assessment of the DOW small-scale chemistry experiments, we concluded that small-scale chemistry experiments can benefit all schools regardless of their funding or lab quality. Schools that without laboratories that teach mostly from theory would benefit the most from small-scale experiments; exposure to hands-on learning, as opposed to lecture-style learning, has been shown to increase student interest and engagement (Hall et al., 2016). Due to the lower price, small-scale materials would be easier to purchase than full-scale glassware, providing more opportunities for hands-on experience. Additionally, schools with larger budgets and full-scale laboratories could also benefit from small-scale chemistry since they can be completed more frequently due to less set up and clean up time.

Although we can conclude that small-scale is more feasible to implement nationwide, we cannot conclude that small-scale is better than full-scale considering the inequity of funding and resource availability throughout Thailand. Many teachers claimed it was essential to teach students full-scale in addition to small-scale, so that students can learn how to handle full-scale laboratory equipment that would be utilized in university and the workforce.

According to the correlation between laboratory quality and student career plans in our data, implementing small-scale chemistry and increasing the amount of hands-on learning throughout Thai high schools could lead to an increase in students pursuing careers in science. This could result in great benefits for the Thai economy as students could hopefully fill the open positions in the STEM field.

REFERENCES

Atagi, R. (2011). Secondary teacher policy research in Asia: secondary teachers in Thailand. *Corporate author: UNESCO Office Bangkok and Regional Bureau for Education in Asia and the Pacific [811]*. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000215102>

The article describes various strategies used in Thailand to increase the number of professional teachers. The article elaborate standards and requirements for teachers at specific schools (small, big, rural urban, and specific regions) within Thailand, describing the variety of standards based on the location of the school. Additionally the source elaborates on the evolution of the Thai education system. This resource is beneficial to our project to help us understand the evolution of Thai education and the history of the teachers in Thailand. If the teachers do not have the proper education to teach chemistry in the classroom with confidence, the success of DOW Chemistry Classroom will hopefully strengthen teachers qualification. This source was used to understand the importance of the DOW Chemistry classroom to Thailand's education and validate the reason for our research.

Avvisati, F., Echazarra, A., Givord, P., Schwabe, M.(2019). Programme for international student assessment (PISA) results from PISA 2018. *Organization for Economic Cooperation and Development*. Retrieved from https://www.oecd.org/pisa/publications/PISA2018_CN_THA.pdf

This country note displays the results of science test scores from Thai students. It also compares the test scores from Thailand to the average test scores of students from other countries. The test results in this resource demonstrate that Thai students are underperforming in science in comparison to other places in the world. Thailand as a country also has certain areas that obtain higher test scores than other regions of the country. It is important for our group to be aware of the differences in educational achievement throughout the country and world when we analyze our survey results.

Baller, S., Dutta, S., Battista, A., Garrity, J., Lanvin, B., Pepper, R., & LaSalle, C. (2016). The global information technology report 2016: Innovating in the digital economy. *World Economic Forum*. Retrieved from http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf

The Networked Readiness Index was created by the World Economic Forum to “assess countries’ preparedness to reap the benefits of emerging technologies and capitalize on the opportunities presented by the digital transformation.” Countries were assessed over four categories (1) the environment for technology use, (2) networked readiness in terms of infrastructure, affordability, and skills, (3) technology usage by the government, private sector, and private individuals, and (4) the economic and social impact of new technologies. This index provided our group with various data points for us to compare between countries. It was interesting to see how countries with more internet access and better STEM education typically also have a better capacity for innovation and availability of the latest technologies. We cannot assume causation between these data points, but it is important to recognize the correlation between them.

Barsam, A. (2019). Tomorrow’s workforce starts with investing in education today. Retrieved from <https://www.kenan-asia.org/education-investment-thailand-4-0/>

The Kenan Foundation Asia published an article related to the *Thailand 4.0* initiative and workforce in Thailand. The article reveals the need for more workers in science and technology in order to meet Thailand’s goals for the upcoming years. With Thailand’s push to innovate and expand in the technical field, the demand for technical workers is continuing to increase. The high demand for technical workers to innovate and create is even higher in Thailand due to the lack of workers already in the field. The article elaborates that more positions will be created over the years and more students need to pursue a science career. This article is important to understand how the DOW Chemistry Classroom plans to ensure enough students are pursuing a science career path to fill the high demand.

Basu-Dutt, S. (2010). Making chemistry relevant: Strategies for including all students in a learner-sensitive classroom environment.(pp. 1–289). doi:[10.1002/9780470590591](https://doi.org/10.1002/9780470590591)

This book discusses how student’s interest and achievement in science improve dramatically when they make connections between what they are learning and the potential uses of that knowledge in the workplace or the world. The book contains strategies to incorporate project-based learning into chemistry classrooms. It rejects memorization and promotes a philosophy where the teacher acts as a facilitator in helping students construct solutions to

problems. It encourages relating chemistry to current events such as global warming and pollution so that students can see applications of chemistry in the world. This source will help us find valuable teaching methods that the DOW Chemistry Classroom can implement to ensure students are learning not only the educational material, but also the importance of chemistry and how it impacts the world around them.

Bauer, C. F. (2008). Attitude toward chemistry: A semantic differential instrument for assessing curriculum impacts. *Journal of Chemical Education*, 85(10). doi: [10.1021/ed085p1440](https://doi.org/10.1021/ed085p1440)

The Attitude toward the Subject of Chemistry Inventory (ASCI) assessment was created to measure students' attitudes towards chemistry by assessing three major categories that affect interest: anxiety, intellectual accessibility, and emotional satisfaction. The assessment asks students to rank their experience on a five point scale between two contrasting adjectives. For example, a student would rank how they felt during the experiment on a scale from nervous to calm. The adjectives used in the survey have been chosen so that they are contrasting and eliminating as much bias as possible. Our group will be using an adaptation of this assessment to measure if the students are enjoying the experiments used in the DOW Chemistry Classroom program.

Berzina-Pitcher, I., Graves-Wolf, L., Mehta, S., & Seals, C. (2017). Enhancing teacher efficacy for urban STEM teachers facing challenges to their teaching. Michigan State University. *Education Resources Information Center*. Retrieved from <https://files.eric.ed.gov/fulltext/EJ1150083.pdf>

This article from Michigan State University identifies the main obstacles of STEM teachers in urban schools, and if a program called UrbanSTEM improved their experiences. The results showed that the main problems in the teacher efficacy were lack of resources and organization. The UrbanSTEM program encourages teachers to have multiple methods in teaching one concept, in order to be effective for all different kinds of learners. UrbanSTEM also urges teachers to empower their students. This is meant to foster a feeling of confidence amongst the students which would improve their academics. In addition, UrbanSTEM teaches the use of technologies, so the teachers can be confident in the tools they are using to teach their students. The study shows that the UrbanSTEM program was successful in helping teachers develop an efficient and successful STEM classroom. This could be incorporated into our project because we could help the DOW Chemistry Classroom find more than one method of teaching one skill or

concept, as UrbanSTEM does. We also can look into how the teachers interact with their students rather than solely how they teach the students. This study shows the significance of a student/teacher relationship, and it is important that the teachers using the DOW Chemistry Classroom develop a trusting relationship with their students in order for the students to have the most positive experience they can.

Boyd, C. (2014, June). Discover the benefits of microchemistry. *Chem Service Incorporated*. Retrieved from <https://www.chemservice.com/news/2014/06/discover-the-benefits-of-microchemistry/>

The Chem Service Inc article discussed the benefits of Microchemistry which included reduced waste, increased safety, lower costs and reduced time. The article elaborate on the safety of using smaller quantities of chemicals which reduces the amount of waste and limits problems of safe disposal of the chemicals. With smaller quantities students also have to focus on precision, which can also be seen as a benefit in developing students techniques. This article was important to understand all the advantages of microchemistry and the small-scale chemistry kits that DOW has created.

Brown, L., Hackett, G., & Lent, R.W.(2017). Social cognitive career theory. *Career Choice and Development*. (4) 255-311. Retrieved from https://www.researchgate.net/publication/306145850_Social_cognitive_career_theory

In this source by Brown, Hackett, and Lent, the method behind the social cognitive career theory is explained. They talk about the different categories within social cognitive career theory that cause an individual to pursue a certain career path. One of these categories is interest, which is the main focus of our project. This is beneficial to our project because it emphasizes the ways we can structure our questionnaires to gain an understanding of student interest in science.

Bureau of International Cooperation Ministry of Education: Thailand (2017). Thai higher education in brief. Retrieved from <http://www.bic.moe.go.th/>

The Ministry of Education in Thailand published an article that described the Thai education system from primary to secondary level. This article is beneficial to understand the education system and the development over the programs over the years. The overview breaks down the divisions of Thailand's education system. Additionally, the article includes statistics of

enrollment rates at each education level over the years which is beneficial to understand the trends of the years of education. This data is beneficial to our research to ensure the use of enrollment data to measure the success of the DOW Chemistry Classroom takes into account the total enrollment data over the years.

Carriazo, J., Molina, M. (2019). Awakening interest in science and improving attitudes toward chemistry by hosting an ACS chemistry FeSTiVAI in bogotá, colombia. *Journal of Chemical Education*, 96(5), 944-950. doi:[10.1021/acs.jchemed.8b00670](https://doi.org/10.1021/acs.jchemed.8b00670)

In Bogotá, the American Chemical Society partnered with chemistry professionals, professors, and students to orchestrate a chemistry festival. They put on enticing demonstrations of experiments, and also have hands-on experiments. This festival is held for youth students in Bogotá to have a fun way to interact with chemistry outside of a school setting. It provides a more spontaneous learning environment where students don't have to feel stressed or anxious about school. Surveys showed that the festival did generate a more positive outlook on chemistry for the students. The DOW Thailand Group, who is already partnered with the Chemical Society of Thailand, could put on festivals such as this one with the help of the Chemical Society of Thailand and Chulalongkorn University. This could help bring students together in a more informal educational setting, and hopefully increase the love for chemistry as it did in Bogota.

Chemical Society of Thailand. (2008). About Chemical Society of Thailand. Retrieved from <https://www.chemsocthai.org/about/>

This source explains the role of the Chemical Society of Thailand, which is a part of the Science Society of Thailand under the royal patronage. The Chemical Society of Thailand was established after Professor Dr. Kamchonmanun Pichu was invited to a UNESCO event, and was encouraged to expand the program nationally and internationally. The history of Chemical Society of Thailand is explained, which is important to our project because they are one of the major stakeholders.

Chemical Society of Thailand. (2017). Details of DOW-CST Awards. Retrieved from <https://www.chemsocthai.org/wp-content/uploads/2017/11/%E0%B8%9B%E0%B8%A3%E0%B0%E0%B8%81%E0%B8%A7%E0%B8%94%E0%B9%82%E0%B8%84%E0%B8%A3%E0%B8%87%E0%B8%87%E0%>

[B8%B2%E0%B8%99%E0%B8%A7%E0%B8%B4%E0%B8%97%E0%B8%A2%E0%B8%B2%E0%B8%A8%E0%B8%B2%E0%B8%AA%E0%B8%95%E0%B8%A3%E0%B9%8C-%E0%B8%A3%E0%B8%B2%E0%B8%87%E0%B8%A7%E0%B8%B1%E0%B8%A5-DOW-CST-Award-2017.pdf](#)

This document provides the objectives and the information about the DOW-CST Awards. It also goes over the criteria for entering the competition and its overall process. Is it important for us to understand why this contest exists since the Awards competition is part of the DOW Chemistry Classroom program. In simple words, DOW-CST Awards has been established in order to measure how much students learn from the DCC program, and it provides a free space where students can explore their scientific knowledge, as well as creativity, to design an experiment based on real-life applications.

Chemical Society of Thailand. (2019). DOW chemistry classroom. Retrieved from <https://www.chemsocthai.org/%e0b8%94%e0b8b2%e0b8a7%e0b9%80%e0b8%84%e0b8a1%e0b8b5/>

The Dow Chemistry Classroom is a cooperation between the Chemical Society of Thailand and the DOW Thailand Group. The objective of the DOW Chemistry Classroom is to promote the teaching and learning of chemistry by using small-scale chemistry experiment techniques that are easy to implement in classrooms and have simple waste removal. This website reviews the overall picture of the small-scale laboratory and illustrates the goal of the program: to increase students' interest in science through small-scale, relatable experiments.

Chuangchote, T., Noi-Am, N., & Tisadondilok, L. (2017). "Dow Chemistry Classroom" Expanded to Elementary School Level, Inspiring the Love of Science among Thai Youth. Retrieved from <https://th.dow.com/en-us/news/press-releases/inspiring-the-love-of-science-among-thai-youth>

This article written by the DOW Thailand Group describes the DOW Chemistry Classroom's mission, and who uses this program. It tells readers that there is a total of 123 teachers from 65 schools in Thailand that attend trainings; these trainings show teachers how to incorporate small-scale chemistry laboratories into their high school classrooms. This article highlights how the DOW Chemistry Classroom has expanded to the elementary school level in 2017. These trainings for the teachers are held at a hotel in Rayong, and its practices have

expanded to other ASEAN countries. It is also recognized by UNESCO, and practiced internationally in Europe, South America, and other countries in Asia. This is important to our project because it helps us to understand the widespread impact and goal of the DOW Chemistry Classroom.

Corporate Finance Institute Education Incorporated. (2015). R-squared definition, interpretation, and how to calculate. *Corporate Finance Institute*. Retrieved from <https://corporatefinanceinstitute.com/resources/knowledge/other/r-squared/>

This article describes the definition of, how to interpret, and how to calculate R^2 . It explains the linear regression model, and goodness of fit. In addition, it explains that R^2 can show how well data fits the given model, and if the variance in the observed variable can be explained by the independent variable. This is significant to our data because it can tell us how well our data fits the model, and how much of the variation we see in the response variable can be attributed to a given factor.

DOW Thailand Group. (2019a). About us. Retrieved from <https://th.dow.com/en-us/about-us>

This article describes the DOW Thailand Group, and its goals and accomplishments. The DOW Thailand Group is the largest chemical manufacturing base in the Asia-Pacific region; its mission is to bring sustainability and collaboration to the country of Thailand. They are recognized locally and globally for their manufacturing and have been established for over 5 decades. They are working to reshape the way businesses intersect with society to make Thailand more environmentally friendly. This source helps us to understand the mission of our sponsors, and their reason for investing their time into the DOW Chemistry Classroom.

DOW Thailand Group. (2019b). All plants of DOW Thailand receive good governance awards for environmental and safety excellence. Retrieved from <https://th.dow.com/en-us/news/press-releases/all-plants-of-dow-thailand-receive-good-governance-awards>

This source explains that the DOW Thailand Group has fifteen locations, all of which received the “Good Governance Awards for Environmental and Safety Excellence” which is known as the ‘Green Star Award’. This is due to their management of environmental safety and

sustainability, as well as Corporate Social Responsibility management. This is important to our research because it shows us how reputable and involved our sponsors are.

Educational Testing Institute. (2019). National educational testing report system. Retrieved from <http://www.serviceapp.niets.or.th/onetmap/>

This website shows the test scores of the National Education Testing Report System (ONET) throughout the years. It compares the scores from students in different parts of Thailand. In addition, different grade levels can be compared, and information from years 2016-2018 can be viewed. The test scores can be displayed on a map and allows us to understand the different quality of education by region, which can be applied to our project when we are collecting data from schools in different regions of Thailand.

Faikhamta, C., Ladachart, L. (2016). “Science education in Thailand: Moving through crisis to opportunity”. In *Science Education Research and Practice in Asia: Challenges and Opportunities* (pp. 197–214). doi: [10.1007/978-981-10-0847-4_11](https://doi.org/10.1007/978-981-10-0847-4_11)

This research article recalls the history of educational reform in Thailand throughout the past few years. It explores the possible variables that have influenced Thai science curriculum standards in modern day. This includes cultural and political influences, and the readiness for teaching of science instructors in Thailand. The authors conclude that the science curriculum needs to be looking for reasons for Thai students’ low performance in science standard examination (ONET) as well as their low PISA results. Finally, it gives suggestions on how science education in Thailand could be improved. This is relevant to our project because it describes some problems in education in Thailand which we can use to help DOW target areas of weakness in the Thai education system in the future.

Ferreira, L.M.R., Carosso, G.A., Montellano Duran, N., Bohorquez-Massud, S.V., Vaca-Diez, G., Rivera-Betancourt, L., ... Mostajo-Radji, M. (2019). Effective participatory science education in a diverse Latin American population. *Palgrave Commun* 5, 63. doi: [10.1057/s41599-019-0275-0](https://doi.org/10.1057/s41599-019-0275-0).

Ferreira’s article examines the impact of implementing a low-cost Biology course into high schools and colleges in Bolivia. Similar to the DOW Chemistry Classroom, the program was created to increase the youth’s interest in science in the hopes of encouraging them to enter a

STEM career. Ferreira's training methods can be used as a comparison to the DOW Chemistry Classroom because the goal of the DOW Chemistry Classroom is to also increase student interest in science. Additionally, the assessment methods used to measure the success of this program in Bolivia can be adapted to properly assess the success of the DOW Chemistry Classroom.

Fleischer, L., Bogiatzis, A., Asada, H., & Koen, V. (2018). Making growth more inclusive in Thailand. *Paris: Organisation for Economic Cooperation and Development (OECD)*.

<https://pdfs.semanticscholar.org/1b11/8d23e203754af84d151ef71756678aa08746.pdf>

This source uses test scores to compare Thailand's education to other ASEAN countries. Results show that Thailand is ranked higher in comparison to other countries when it comes to educational equity (how socio-economic differences affect performance). However, overall performance amongst Thai youth has been deteriorating in comparison to other countries; the number of low-performing students in science and reading has increased, and the number of high-performing students has decreased. This is important to keep in mind when comparing data from Thai schools to other countries. In addition, it is useful in the background section of our report because it describes where Thailand's education ranks globally.

Fouad, N. (2014). Social cognitive career theory: Introductory review. *Career Theory and Practice: Learning Through Case Studies*. Retrieved from <https://www.nae.edu/File.aspx?id=126530>

This article discusses aspects of social cognitive career theory (SCCT). SCCT has been applied in vocational psychology to explain how individuals' career interests develop, how they make career choices, and how they determine their level of performance. SCCT describes three linked variables that impact a person's career development: self-efficacy beliefs, outcome expectations, and goals. It also proposes that contextual variables could act as a perceived barrier to outcome expectations. For example, a young man with high interest in helping others and medicine may not go into nursing because of his perception that nursing is not an appropriate occupation for a man. Support, or lack of, from his family could also influence his decision to pursue a nursing career. This is helpful to our project since it is important for us to keep in mind these different factors of interest development. Though the DOW Chemistry Classroom may capture a student's interest, if the student's family does not support their decision to pursue science then they may choose not to pursue a science career despite their interest.

Ganti, A. (2019). What is the correlation coefficient?. *Investopedia Corporate Finance and Accounting*. Retrieved from <https://www.investopedia.com/corporate-finance-and-accounting-4689821>

This website describes the correlation coefficient, r , and how to interpret it. It describes r as a number between -1.0 and 1 that can show how closely correlated two variables are. The closer to 1.0 or -1.0, the stronger the correlation. This is very important to our statistical analysis of the correlation between student interest and varying factors because it can portray the correlation between our variables of interest.

Hall, A., & Miro, D. (2016). A study of student engagement in project-based learning Across multiple approaches to STEM education programs. *School Science and Mathematics*, 116(6), 310–319. Retrieved from <https://doi.org/10.1111/ssm.12182>

This study investigated the implementation of project-based learning (PBL) activities in various STEM education settings to examine the impacts on student learning. Results showed that after completing engineering projects students had more confidence in math and science, higher interest in engineering careers, and more awareness of the nature of engineering. PBL typically includes higher-order questioning, student reflection, problem solving, content integration, and teamwork. After implementing a STEM-focused PBL, it was found that students had an increased knowledge as well as more positive attitudes toward STEM careers. This is important to our project because if PBL is the most effective way to teach STEM and results in positive attitudes towards STEM then we could suggest DOW incorporates this into their program.

Handson, R. (2014). Using small-scale chemistry equipment for the study of some organic chemistry topics - a case study in an undergraduate class in Ghana. *European Journal of Basic and Applied Sciences*, 2(2). Retrieved from <https://www.idpublications.org/wp-content/uploads/2015/06/USING-MICRO-SCIENCE-EQUIPMENT-TO-FACILITATE-THE-STUDY-OF-QUALITATIVE.pdf>

This case study conducted on students in Ghana investigates the impact of the Small-Scale Chemistry Experiment (SSCE) in an organic chemistry class. They state that the practice of

completing practical work increases comprehension of the subject. However, the cost of resources and the increasing number of students in the classrooms are providing a barrier to implementing practical work in classrooms. 110 undergraduate students participated in a study where small-scale techniques and materials were introduced into their classrooms to test for feasibility and likeableness. Researchers were able to assess feedback from the participants with the use of questionnaires with a mix of open and closed ended questions. Results showed that the majority gained confidence in learning science, enjoyed the hands-on experience, and had an enhanced understanding. Only some experienced difficulties. This is relatable to the idea behind the DOW Chemistry Classroom: that small-scale experiments are simple to implement, and enjoyable for students.

Hensen, C., & Barbera, J. (2019). Assessing affective differences between a virtual general chemistry experiment and a similar hands-on experiment. *Journal of Chemical Education*, 96(10), 2097-2108. <https://pubs.acs.org/doi/pdf/10.1021/acs.jchemed.9b00561>

A study at Portland State University which was completed by Hensen and Barbera published in the *Journal of Chemical Education* assesses two types of lab learning styles: virtual and hands-on. The assessment method uses an adaptation of the Attitude toward the Subject of Chemistry Inventory (ASCI). Results showed that the students who participated in the virtual methods scored lower in emotional satisfaction, intellectual accessibility, usefulness of the lab, and equipment usability. However, the scores of this group varied depending on which teacher's assistant instructed the lab. This assessment type can benefit our group assessment of the experiments used in the DOW Chemistry Classroom in three distinct categories of emotional satisfaction, intellectual accessibility and anxiety to effectively assess the success of the program.

Johnson, J, Karisan, D., Macalalag, A. (2019). The effect of methods course on pre-service teachers' awareness and intentions of teaching science, technology, engineering, and mathematics (STEM) subjects. *Education Resources Information Center*. Retrieved from <https://www.ijres.net/index.php/ijres/article/view/461/pdf>

In Turkey, a STEM methods course was offered to pre-service teachers. A study was conducted by offering the subjects a survey before and after the course, to determine how their understanding of STEM and intentions of teaching STEM had changed. The STEM methods course had the pre-service teachers solve problems by completing small group activities. Results

showed that both the awareness and intentions of teaching STEM overall increased after attending this course. This is another course from a different country that can be used as comparison to how the DOW Chemistry Classroom teaches its participants. Any of the activities shown in this article can be offered and compared to the DOW Chemistry Classroom training. Also, this program specifically reaches out to pre-service teachers. We could use the methods in this article to potentially compare to DOW, and provide suggestions depending on the conclusions we draw from our data.

Khayyat, N. T., & Lee, J. (2015). A measure of technological capabilities for developing countries doi: <https://doi-org.ezproxy.wpi.edu/10.1016/j.techfore.2014.09.003>

This study was done to develop an index to measure the innovativeness of developing countries and to investigate the role of science and technology in enhancing the rate of innovation. After completing their study, they recommended that governments (1) allocate a significant share of their budgets to factors that enhance technological capability such as science education, education enrollment rates, and internet connectivity, (2) modify school curriculums to emphasize creativity and spontaneity, and (3) encourage local organizations to conduct specialized training programs to promote innovation activities. The group had other recommendations as well such as relaxing taxes for innovative products/processes, but the first three (especially the third) relate to our project most directly.

Koonprasert, T. (2019). When tutoring overtakes teaching. Bangkok Post. Retrieved from: <https://www.bangkokpost.com/opinion/opinion/1612534/when-tutoring-overtakes-teaching>

This source describes how the Thai norm focuses heavily on standardized tests, but the materials covered in class were found to be insufficient to prepare the students for exams. Therefore, it requires the parents to seek for extra courses that can teach their children a more comprehensive understanding of the curriculum. As a result of the pressure of taking extra tutoring schools to get ready for the entrance exam, the students did not feel the importance of paying attention in class. In order to get rid of this issue, the Thai education system should give more attention to the materials covered in class and the science curriculum in Thailand. This is important when assessing the experiments of the DOW Chemistry Classroom. It is essential that these experiments follow the curriculum and are adequately teaching students the required material.

Krief, A. (2019). International Organization for Chemical Sciences in Development. Retrieved from http://www.iocd.org/v2_index.shtml

This website expands on the International Organization for Chemical Sciences in Development (IOCD) and their ideals of expanding nations economic growth through promotion of sustainable chemistry. This source allows us to understand the collaboration and ideals of the Chemical Society of Thailand's between other nations both developed and low-income nations. Through the understanding of the IOCD goals we can understand the Chemical Society creation of the DOW Chemistry Classroom in Thailand to expand sustainable chemistry in Thai youths and impact the Thai economy.

Krotintakom, S., Noi-Am, N., & Krotintakom, S. (2017). Dow Thailand receives Professor Dr. Tab Nilanidhi Foundation's award. Retrieved from <https://th.dow.com/en-us/news/press-releases/dow-thailand-receives-professor-dr-tab-nilanidhi-foundations-award>.

Directors of the DOW Thailand Group received the 2016 Outstanding Organization in Promoting Science Education in Thailand Award. This is due to DOW's contributions to research in science, and development of science projects that are key to Thailand's education and economic growth. This source gives background information on DOW, and their goal as a chemical manufacturing company. It is used in the background section of our report to describe our sponsors accomplishments.

Landrum, A., Hilgard, J., Akin, H., Li, N., & Kahan, D. (2016). Measuring interest in science: The science curiosity scale. Retrieved from https://www.researchgate.net/publication/301293576_Measuring_Interest_in_Science_The_Science_Curiosity_Scale

This student aimed to create a "science curiosity scale." It contained valuable information on sample questions as well as pros and cons to particular methods of questioning. For example, the study noted that when you ask someone to self-report their interest in something, they are likely to give the "socially desirable response." If you ask someone to what extent they agree with statements such as "I'm curious about the world in which we live," and "I find it boring to hear about new ideas," subjects will likely answer agree then disagree respectively since those are

“socially desirable responses.” One way this study combatted this bias was they disguised the purpose of the survey by making it seem that they were asking about your interest in a variety of topics other than science (e.g., sports, entertainment, business, and politics). This way, there was no reason for participants to think that the researchers were specifically interested in their science interest and it encouraged participants to honestly report their interests. This is important to keep in mind when surveying our subjects.

Larmer, J. (2015). Gold standard PBL: Essential project design elements. *Buck Institute of Education*. Retrieved from <https://www.pblworks.org/blog/gold-standard-pbl-essential-project-design-elements>

The Buck Institute has developed the “gold standard” for project-based learning (PBL). If done successfully, PBL helps students learn how to apply knowledge to the real world and use it to solve problems, answer complex questions, and create high-quality products. Additionally, students learn a lot of “soft skills” through PBL, such as how to think critically, work well with others, and manage themselves effectively. These skills are referred to as “21st century skills.” This relates to our project since one of the goals of the *Thailand 4.0* initiative is to transform Thais into “Competent human beings in the 21st Century.” Project-based learning implemented in the DOW Chemistry Classroom can help provide Thai youths with these skills and help them succeed as they move forward in their careers.

Mongkhonvanit, J. (2017). Thailand’s dual education system: A way forward. *Higher Education, Skills and Work - Based Learning*, 7(2), 155-167. Retrieved from <http://dx.doi.org/10.1108/HESWBL-09-2016-0067>

Mongkhonvanit’s study compares the Thailand dual education system with four other countries Germany, South Korea, Australia, and Singapore to understand the lack of graduates pursuing a career in the technical workforce. The report analyses Thai’s dual education system which consists of technical and vocational education. Although the dual education was endorsed by the government in 2014 to increase employment in the technical fields, not all institutions enforce this method. Therefore, the technical field still lacked numbers. The source gives recommendations to strengthen the Thai dual education system by implementing ideas from the other countries. Overall, this source is useful to understand the importance of youth interest in STEM in Thailand. The country is in desperate need for youths to pursue a technical career paths

because there are a lot of openings. The Dow Chemistry Classroom knows it is essential to grab the attention of youth at a young age to pursue a technical career.

OECD. (1999). "Introduction". In *Measuring Student Knowledge and Skills: A New Framework for Assessment*, 7–11. Retrieved from <http://www.oecd.org/education/school/programmeforinternationalstudentassessmentpisa/33693997.pdf>

OECD is an international organization that is responsible for designing the PISA examination which measures students' performance in science, mathematics, and English literacy. This is used in 80 countries around the world. This article explains the objectives of the PISA examination, and tells us which countries need to ameliorate their education curriculum.

OECD/UNESCO. (2016). Education in Thailand: An OECD-UNESCO Perspective. *Reviews of National Policies for Education*. Retrieved from https://www.oecd-ilibrary.org/education/reviews-of-national-policies-for-education_19900198

This article was a review of national policies for education in Thailand written from the perspective of OECD-UNESCO (Organization for Economic Cooperation and Development and the United Nations Educational, Scientific and Cultural Organization). It discussed the reforms that Thailand has made to its education system and reviews the outcomes and challenges that came with this change. It suggested areas for improvement in the Thai education system and specifically recommended that Thailand should improve in the following: creating educational standards, assessing student progress, preparing teachers to implement the revised curriculum, and improving the use of information and communications technology. Similar to other articles, it highlighted how rural areas of Thailand are struggling to keep up due to less access to educational tools such as a lack of high-speed internet. This is important background information for us to be aware of since we need to ensure that the DOW Chemistry Classroom is not trying to implement things that require internet access or extensive training since these things seem to be causing programs to be unsuccessful.

Pajonporn, S. (2018). The NSM of Thailand in collaboration with DOW and CST serves to promote science education for the forthcoming Thailand 4.0. Retrieved from <https://www.mhesi.go.th/main/th/34-news/news-gov/7047-dow-cst-award>

The article mentions the role of NSM in relation with DOW and CST to organize the CST Awards, in order to promote Thai science education amongst middle and high school students. The NSM focuses on equality in science education and motivating learners to participate in extracurricular activities, which in the long run, may increase in love of science in Thai youths. In short, this website allows us to acknowledge the stakeholders and their impact towards the DOW Chemistry Classroom program.

Rothwell, J. (2013). The hidden STEM economy. *Educational Resources Information Center*: Brookings. Retrieved from <https://www.brookings.edu/wp-content/uploads/2016/06/TheHiddenSTEMEconomy610.pdf>

This report found that “workers in STEM fields play a direct role in driving economic growth.” They also found that in the US, STEM jobs have doubled as a share of all jobs from less than 10% in 1980 to 20% in 2010. Additionally, job growth, employment rates, patenting, wages, and exports are all higher in more STEM-based economies as well as lower income inequality. This is important to our project because it shows that if the DOW Chemistry Classroom leads to more workers in STEM fields, this could also lead to economic growth in Thailand.

Royal Society of Chemistry. (2009). Microscale chemistry. Retrieved from <https://www.stem.org.uk/resources/collection/4034/microscale-chemistry>

This digital database compiled by the Royal Society of Chemistry in the United Kingdom displays over 60 small-scale chemistry experiments. If the DOW Chemistry Classroom created a digital collection of the procedures for the intended lab kits, then the teacher would have a website to refer to. Additionally, a website like this could help teachers expand on their ability to create experiments and learn more about small-scale experiments that have been created. We believe teachers would benefit from having sites to refer to when creating their own small-scale experiments.

Royal Thai Embassy, Washington D.C. (2020a). Thailand 4.0. Retrieved from

<https://thaiembdc.org/thailand-4-0-2/>

Thailand 4.0 is an economic model to create a value-based economy driven by innovation, technology and creativity. The model aims to increase research and development spending, reduce social disparity, teach Thais 21st century skills, improve universities, and become more environmentally conscious. They want the work force to shift to include high skilled labor, more tech start-ups, and smart farming. This is important to our project because the DOW Chemistry Classroom is a part of the Thailand 4.0 movement. DOW Chemistry Classroom helps to improve the country's competency through technology, innovation, and creativity, and prepares the youth to be ready for the fast-paced and competitive world.

Royal Thai Embassy, Washington D.C. (2020b). National strategy Thailand 4.0 officially launched.

Retrieved from <https://thaiembdc.org/2018/10/22/national-strategy-thailand-4-0-officially-launched/>

Thailand recently launched a national strategy called "Thailand 4.0". This strategy, initiated by the government, is a 20-year plan to promote innovation, creativity, research and development, and more advanced and more environmentally friendly technologies. The goal of this plan is to secure Thailand's wealth and sustainability in the hopes of making Thailand a high-income country, and to protect the environment. Therefore, the government is improving the education and human resource development system in the hopes of bringing these plans to fruition. The Thailand 4.0 initiative, as stated in the description of the above article, is part of the reason behind the DOW Chemistry Classroom. The education reform is meant to be brought to rural schools through the methods of the DOW Chemistry Classroom. Understanding the guidelines and expectations behind Thailand 4.0 can help us implement plans to ensure that the education system is being affected by the DOW Chemistry Classroom in ways that will align with this 20-year plan.

Scola, N., & Paul Metcalf, H. (2016). Guiding principles for effective science and technology/engineering education. *Massachusetts Department of Elementary and Secondary Standards*. Retrieved from

<http://www.doe.mass.edu/frameworks/scitech/2016-04/GuidingPrinciples.pdf>

The published document “Science and Technology/Engineering Learning Standards illustrates the framework behind Massachusetts Education of science and technology at all grade levels pre-K- 12th grade. The document breaks down the whole Massachusetts education system by grade stating the key subjects that should be taught at each level and listing the skills that should be developed at each grade due to the lessons taught. My group can create a parallel between the Massachusetts education system and Thai education system in relation to STE and understand if the levels match up. If the levels are not at the same point alteration to the DOW Chemistry Classroom can be altered to ensure students education is advancing at an appropriate pace. Additionally, an understanding of each age level’s ability to learn is important to ensure the lab experiments in DOW Chemistry Classroom are appropriate in difficulty level. If a lab experiment is not pushing the students, interest will be lost due to boredom.

StatTrek. (2020). Two-sample t-test: Definition. Retrieved from

<https://stattrek.com/statistics/dictionary.aspx?definition=two-sample%20t-test>

This site describes how a two-sample t-test can be used to test the statistical significance of the difference between two means. It describes the methods of this hypothesis testing as well as how to calculate the t-score and p-value and then interpret these values. This is important in our statistical analysis when comparing two means (ex. mean interest in science between DOW and non-DOW schools) to determine the probability of our findings to exist in the entire population.

Tesfamariam, G., Lykknes, A., & Kvittingen, L. (2014). Small-scale chemistry for hands-on approach to chemistry practical work in secondary schools: Experiences from Ethiopia . *African Journal of Chemical Education*, 4(3), 48-94. Retrieved from

http://www.faschem.org/AJCE/AJCE_2014_May_Special2.pdf

This report published in the African Journal of Chemical Education studied the differences between students who performed small-scale chemistry experiments and those who participated in a theory only class. The study was performed in Ethiopia which used a small-scale chemistry experiment kit that was made in South Africa. The study concluded that the students who participated in the small-scale experiments benefited from the hands-on learning. This source is valuable to understand that implementation of small-scale chemistry kits in other

developing countries. Additionally, the source allowed us to understand other benefits of small-scale experiments such as small quantities, low cost, and safety.

Tisadondilok, L. (2017). Dow Chemistry Classroom project expands to elementary level across Thailand. Retrieved October 28, 2019, from <https://corporate.dow.com/en-us/news/press-releases/dow-chemistry-classroom-project-expands-to-elementary-level-across-thailand.html>.

This article, published on the DOW website, provides details of the DOW Chemistry Classroom program. It discusses the objective of the program: “to equip elementary school teachers with innovative experimental techniques that can help make chemistry class safer, more interesting, and more relatable.” The program understands that teachers are the key drivers in developing the education system. It recently has expanded to elementary schools in addition to high schools. Over 600 teachers, and 300 schools have become a part of this program nationwide. This is important to our project because it can help us assess the role of teachers in the DOW program.

The World Bank. (2019). The world bank in Thailand. Retrieved from <https://www.worldbank.org/en/country/thailand/overview>

This website was developed by the World Bank Group, an organization that frequently partners with the Kingdom of Thailand to promote sustainable and economic initiatives. The website had good background information about the economy of Thailand and discussed their growth from a low-income to upper-middle income country in less than a generation. It discussed the decline in poverty, expansion of health insurance, and increase in education. It stated how the quality of learning is not equal to the years of school they receive, and how even though the average Thai student obtains 12.4 years of schooling, if you adjust that number to account for the quality of their education they only obtain the equivalent of 8.6 years at an advanced institution. It is important for our group to understand the current state of the educational system since our project aims to improve it.

UNESCO. (2006). UNESCO teaching and learning materials. Retrieved from <http://www.unesco.org/new/en/natural-sciences/special-themes/science-education/basic-sciences/microscience/unesco-teaching-and-learning-materials/>

The UNESCO digital library has published both teaching and learning material on a variety of small-scale chemistry experiments. The creation of a digital database like this for all the DOW small-scale kits would be beneficial for teachers to retrieve information about each kit. Additionally, his website could be useful to share with the trained teachers so they can refer to the site when they have questions about small-scale experiments in general.

UNESCO. (2011). Small is beautiful . *A World of Science*, 9(3), 17-19. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000193840.page=17>

This article, published in *A World of Science*, elaborated on the global micro-science project impact over the last 15 years. The article contains details about the creation of the original kits created by RADMASTE in South Africa and the evolution of the kits over the years. In addition, the article elaborates on the integration of the kits into other nations' curriculum. This article is beneficial to understand the importance of small-scale in developing countries. Also, the article informs us about other kits that have been created over the years which allows us to compare the kits to the ones created by DOW. We were able to use this to understand how DOW Chemistry Classroom expands beyond other existing small-scale kits.

UNESCO. (2015). The global microscience experiments project: Practical teaching aids for secondary schools . *UNESCO Natural Sciences Sector, Division of Basic and Engineering Sciences*, , 1-6. Retrieved from http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_bes_microscience_EN.pdf

This document presents the key factors of the Global Microscience Experiment Project created by UNESCO centered around South Africa. The presentation discussed the main objectives of the project, which included promotion of practical science work to increase interest in science through hands-on learning. The presentation elaborates on the teaching and learning material created by the project and where to access the information; although, the material needs to be adapted to each individual nation's curriculum before it can be implemented. The presentation continues to elaborate on the kits that have been created in various locations such as South Africa and Thailand. This presentation allowed us to understand the history of small-scale experiments and projects put in place to increase the use of microsciences across the world.

United Nations Development Programme. (2018). Human development index (HDI). Retrieved from <http://hdr.undp.org/en/content/human-development-index-hdi>

The Human Development Index was created by the United Nations Development Program to assess the development of a country. It takes in the factors of life expectancy, years of schooling, and GNI per capita to calculate an HDI value between 0 and 1 (1 being the most developed). The United States has an HDI value of 0.924 and is ranked 13th in the world. The average life expectancy is 79.5 years, expected years of schooling is 16.5, mean years of schooling is 13.4, and GNI per capita is 54,941 (PPP\$). In comparison, Thailand received an HDI value of 0.755. The average life expectancy is 75.5 years, expected years of schooling is 14.7, mean years of schooling is 7.6, and GNI per capita is 15,516 (PPP\$). There is a noticeable difference in both the mean years of schooling and GNI per capita between the US and Thailand. More research needs to be done to see what factors might cause these differences. It is important that our group understands these cultural/economic differences as we progress with our project.

Winters, J. V. (2014). *STEM graduates, human capital externalities, and wages in the U.S.*. Retrieved from <http://ftp.iza.org/dp7830.pdf>

This study found that it is beneficial to increase the number and share of STEM graduates in the labor force because STEM graduates appear to create large external benefits. In fact, there seems to be a positive effect of STEM graduates even on the wages of workers without college degrees and workers with degrees in non-STEM fields. They also found that non-STEM college graduates created positive wage externalities, but STEM graduates created much larger ones. This is important to understanding the large-scale effects our project could have on the economy.

APPENDIX A: ADDITIONAL BACKGROUND INFORMATION

A1: Number of teachers needed by subject in schools experiencing a shortage

Table 5.3. Number of teachers needed by subject in schools experiencing a shortage, 2013/14 school year

Subject	Number of teachers needed
Science	6 173
Mathematics	6 031
Foreign language	5 809
Thai	4 764
Arts	4 493
Vocational and technology	3 420
Social, religious and culture	3 105
Early childhood	2 884
Health and physical education	2 707
Computing	2 594
Special education	1 700
Primary	1 351
Psychology and counsellor	1 233
Education administrator	825
Librarian	607
Total	47 696

Source: (OECD/UNESCO, 2016)

A2: Interview with Doctor Professor Heilman (WPI Chemistry Professor)

Tips for Surveying	Assessment Methods	Project Based Learning	Implementation of New WPI Chemistry Curriculum
1) <u>Consult experts</u> on designing non bias assessments ➤ Wording of questions impacts results (not too open ended and can't be guided to answer) ➤ Assessment is hard	1) <u>Self reflection</u> is extremely beneficial to both students and teachers ➤ Student benefit: understand what they have learned or haven't, if they have not learned reflect on what factors impacted that ➤ Teachers benefit: get around assessment policies	1) Use Buck Institute of Learning's <u>wheel of excellence</u> to construct project based learning ➤ Collaboration ➤ Reflection	1) Stimulated <u>independent thinking</u> to create procedures ➤ Creating own procedures was realistic to real STEM field ➤ Collaboration between students on failures and successes of experiments
2) When surveying students in particular they are considered "human subjects" in an experiment ➤ <u>Must get approval</u> from Institutional Review Board	2) Assess <u>different metrics</u> ➤ Each question should target only one aspect of the student's learning experience ➤ For example, the question should not talk about what they learned AND what they liked, those should be different questions	2) Students <u>learn more when they can communicate</u> and work through problems together	2) <u>Elevated the whole chemistry program</u> because of what was expected of the students at the general class level ➤ Students who completed new curriculum had no complaints about 2000 level difficult, while past years complained
3) The survey legally <u>cannot be made mandatory</u> , so it is hard to get a good response rate	3) Data needs to be <u>collected in a controlled manner</u> ➤ When measuring the impact of projects on exam grades too many other variables to create correlation	3) "Students believe each other more than they believe me" ➤ <u>Peers tend to trust the experiences of other peers</u> over the advice of professors	3) <u>Initial backlash</u> from teachers and students due to hazing mentality ➤ Students compared it to past experiences and thought it should be the same level of difficulty as past students ➤ Teachers wanted to teach students <u>in the same traditional way</u> that they had learned it ➤ More work for teachers to learn a new teaching style
How does this relate to our project? 1. We should use experts to create an assessment for non-biased responses 2. Self reflection by students is critical for students to recognize the significance of what they've learned a. Through this reflection, teachers can gain a more accurate representation of how the students benefited from and how the students struggled in the class 3. Collaboration and peer learning is essential to advancement 4. Backlash will occur when implementing new ideas			

A3: Comparable Programs to DOW Chemistry Classroom

Analyzing programs comparable to the DOW Chemistry Classroom can be extremely beneficial. Specific laboratory techniques, teacher training, and assessments of student learning used in these programs can be adapted to improve the DOW Chemistry Classroom and Thai curriculum.

A3.1: Comparable Program Summaries

In Bogotá, Colombia, the American Chemical Society (ACS) partners with chemistry professionals, professors, and students to organize a chemistry festival called the "Festivales de Química". This festival is an event held outside of a formal academic setting. They perform demonstrations of experiments and hands-on activities for students and families to participate in. It provides a more spontaneous learning environment where students don't have to feel stressed or anxious about school (Carriazo et al., 2019). In October of 2017, an assessment of this festival was done by the organizers to determine the effectiveness of the event. Surveys showed that the festival generated a more positive outlook on chemistry for students and other attendees. Overall,

the results showed that the students' opinions on chemistry became more positive after participating (Carriazo et al, 2019).

In Turkey, an undergraduate program started by university professors was created to directly impact pre-service teachers. A total of 53 pre-service elementary school teachers design and participate in small-scale activities and experiments that would be found in a youth STEM classroom. The instructor would provide the pre-service teachers with a real-world problem and have them come up with a solution through design and/or experimentation. A questionnaire was given to the subjects before and after the course. Results showed that both STEM awareness and intentions of teaching STEM overall increased after attending this course. Survey showed that this is because pre-service teachers felt more equipped and knowledgeable in STEM areas and had a greater overall understanding of how to teach specific concepts in STEM (Johnson et al., 2019).

Bolivia created a low-cost biology course for high school and college students to encourage a career path in STEM. This program in Bolivia was created to engage students of all demographics through interactive activities (Ferreira et al., 2019). The main challenges in encouraging students to pursue STEM were lack of resources, priority of other subjects, and limited coverage of each subject. To overcome the lack of resources and money, the country retrieved recycled equipment from United States' universities. The teachers were trained in project-based learning, their specific subject content, and in ways to diffuse difficult classroom situations (Ferreira et al., 2019) Everyday students completed a five question quiz before and after each lesson to assess their learning. In the end, all seven programs successfully increased the level of STEM knowledge in all the students, which demonstrates that a hands-on learning approach is successful for students from a variety of demographics in Bolivia.

A program in the United States, UrbanSTEM, aims to identify and overcome the main obstacles of STEM teachers in urban schools in Michigan. Forty-nine teachers that participated in UrbanSTEM were encouraged to have multiple methods in teaching one concept to be effective for all different kinds of learners. In addition, UrbanSTEM trains teachers in the newest technologies so that they can implement them in their classrooms (Berzina-Pitcher et al., 2017). The teachers were assessed using the Teacher Efficacy Scale once in June of 2017, once in December of 2017, then in May of 2018. Results showed that the main problems in the efficacy of their teaching were lack of resources and organization of the course. The study shows that the UrbanSTEM program was successful in helping teachers develop a plan against their classroom's specific obstacles by providing direct suggestions and plans to combat them (Berzina-Pitcher et al., 2017).

In 2017, Worcester Polytechnic Institute implemented a project-based learning (PBL) curriculum into the first-year general Chemistry sequence. This program was based off the Buck Institute wheel for PBL. Students were expected to produce their own protocols to reach a desired outcome which pushed them to collaborate to determine the successes and failures of each procedure. As a result, the chemistry department was able to set higher expectations for independent learning due to the high level of expectations initially set at the first year-levels. Although the implementation of this new program advanced students' education, the department faced backlash from faculty and students during the first year due to the difficulty of the program, and from some professors who wished to stick to the traditional methods. A self-

reflection assignment completed by the students revealed that even though they disliked the high expectations and workload, they valued the experience and the hands-on learning.

A3.2: Comparison of Comparable Programs

Below is the table , which compares some of the comparable programs. In this table, we compared the purpose of the program's assessment, their assessment methods, pros and cons of the program, and how their program compares to the DOW Chemistry Classroom.

	Bogota	Turkey	United States	Bolivia	WPI
Description	<u>Festivales de Química</u> <ul style="list-style-type: none"> American Chemical Society (ACS) partnered with Colombian chemistry professionals and university students to put on chemistry demonstrations and hands-on activities for the youth 	<u>Undergraduate Chemistry Course</u> <ul style="list-style-type: none"> Course offered at university Had pre-service teachers complete experiments that answer broad questions Then adjust the experiments to fit an elementary classroom 	<u>UrbanSTEM</u> <ul style="list-style-type: none"> Yearlong program that trains teachers to use multiple teaching methods, utilize technologies, and implement creative curriculum. 	<u>PBL Courses in Bolivia</u> <ul style="list-style-type: none"> Implements 7 science course loads with 10 hours of discussion-based lecture and 20 hours of projects/labs 	<u>New First-Year Chemistry Curriculum</u> <ul style="list-style-type: none"> More independent, project-based chemistry laboratory implemented in freshman classes Encouraged collaboration and peer learning
Assessment Purpose	<ul style="list-style-type: none"> Identify if student interest in chemistry increased after the festival and which experiments captured students' attention most 	<ul style="list-style-type: none"> Identify teachers' intentions of teaching STEM & understanding of STEM subjects 	<ul style="list-style-type: none"> Identify teachers' challenges, efficacy & how they changed over the course of the program 	<ul style="list-style-type: none"> Assess student interest in the course & their desire to pursue a science career 	<ul style="list-style-type: none"> Assess if project-based learning helped students learn more material & captured their interest
Assessment Method	<ul style="list-style-type: none"> Pre and post chem. interest surveys <ul style="list-style-type: none"> Strongly disagree to strongly disagree (1-5 scale) Rating of favorite experiments <ul style="list-style-type: none"> 1 to 5 scale Qualitative observations of enthusiasm and motivation 	<ul style="list-style-type: none"> Pre, mid, and post survey about intentions of teaching STEM Given before the course, 12 weeks in, and 4 months after <ul style="list-style-type: none"> Strongly disagree to strongly disagree (1-5 scale) 	<ul style="list-style-type: none"> Pre, mid, and post survey Strongly disagree to strongly disagree (1-5 scale) 	<ul style="list-style-type: none"> General demographic questions Pre and post technical exams <ul style="list-style-type: none"> 5 course specific questions Pre and post chem. interest surveys <ul style="list-style-type: none"> 1 - 5 scale Rated all aspects of course <ul style="list-style-type: none"> 1 - 5 scale 	<ul style="list-style-type: none"> Self-reflections that allow students to reflect on the importance of what they learned
Pros	<ul style="list-style-type: none"> Relatable, intriguing experiments Parent involvement Informal STEM education creates a fun environment Organizers trained by ACS 	<ul style="list-style-type: none"> Works with teachers before they enter the workforce Creative thinking by the teachers Entices teachers to include project-based learning in youth classrooms 	<ul style="list-style-type: none"> Directly targets specific problems encountered by teachers Provides teacher development throughout the entire school year 	<ul style="list-style-type: none"> All students gained interest by PBL 80 students wanted to continue to become scientist Teachers training was extensive and included classroom simulation 	<ul style="list-style-type: none"> Project based learning advanced education Self-reflection benefit students and teachers
Cons	<ul style="list-style-type: none"> Ability to attend the event depends on parents Rating of the experiments could be influenced by other factors: <ul style="list-style-type: none"> Communication and persuasive abilities of presenters Materials used in presentation 	<ul style="list-style-type: none"> Was more effective in female pre-service teachers than male 	<ul style="list-style-type: none"> Found that many of the most pressing challenges (student home life, budget cuts, etc.) were not changeable by teachers 	<ul style="list-style-type: none"> High-achieving students did not benefit as much from Project Based Learning as much as low-achieving students 	<ul style="list-style-type: none"> Backlash from students and professors during initial implementation
Usefulness to DOW Research	<ul style="list-style-type: none"> Program outside of the classroom was used to increase student interest 	<ul style="list-style-type: none"> Working with pre-service teachers instead of working teachers could produce a larger impact since experienced teachers may be stuck in their traditional teaching styles 	<ul style="list-style-type: none"> Teacher training and assessment methods 	<ul style="list-style-type: none"> Assessment of student's interest in STEM career Project Based learning was successful 	<ul style="list-style-type: none"> Project based learning Self-reflection as an assessment method

All these programs were similar to the DOW Chemistry Classroom in how they aim to identify teaching challenges and assess if students are learning through PBL while increasing their love for STEM. We can utilize the assessment methods and activities from these comparable programs in our assessment plan and provide recommendations to the DOW Chemistry Classroom based on the successes of these programs. To assess the success of the programs, most of the researchers utilized Likert-style surveys using a scale from one to five, from strongly disagree to strongly agree respectively. These methods of analysis were successful in determining a change in teacher efficacy and students' knowledge and interest in STEM.

☐ Other: _____

4. เพศ (Gender)

Mark only one oval.

- ☐ ผู้หญิง (Female)
- ☐ ผู้ชาย (Male)
- ☐ Other: _____

5. โรงเรียนที่ศึกษาอยู่ (School Name)

6. ประเภทโรงเรียนที่กำลังศึกษาอยู่ (Which of the following describes your school...)

Mark only one oval.

- ☐ โรงเรียนรัฐบาล (I attend public school)
- ☐ โรงเรียนเอกชน (I attend private school)
- ☐ อื่นๆ (other)

7. จังหวัด (School Province)

ความสนใจในวิชาวิทยาศาสตร์ (Student Interest in Science)

8. นักเรียนทำการทดลองเคมีแบบย่อส่วนในวิชาวิทยาศาสตร์หรือไม่ (Do you use DOW small-scale experiments in your chemistry classroom?)

Mark only one oval.

- ☐ Yes
- ☐ No After the last question in this section, stop filling out this form.

9. ข้อใดต่อไปนี้อธิบายห้องเรียนวิทยาศาสตร์ของนักเรียน (Which of the following describes your chemistry class.)

Mark only one oval.

- ☐ ฉันไม่มีอุปกรณ์การทดลองในการเรียนวิทยาศาสตร์ (I do not have labs in my chemistry class.)
- ☐ ฉันมีอุปกรณ์การเรียนแลปที่ครบถ้วนในการเรียนวิทยาศาสตร์ (I have a full laboratory in my science class.)
- ☐ Other: _____

10. ห้องเรียน/ห้องปฏิบัติการสำหรับวิชาวิทยาศาสตร์ของนักเรียนมี... (Check the boxes of the classroom materials that you have available in your classroom or lab...)

Check all that apply.

- ☐ อินเทอร์เน็ต (Internet)
- ☐ คอมพิวเตอร์ (Computers)
- ☐ เครื่องทำความร้อน (Hot plate)
- ☐ เครื่องมือพื้นฐาน บีกเกอร์ หลอดทดลอง ฯลฯ (Basic Laboratory Equipments (beakers, flask etc.))
- ☐ น้ำประปา (running water)
- ☐ Other: _____

11. นักเรียนทำการทดลองครั้งสุดท้ายเมื่อไหร่ (When is the last time you did a lab / experiment in your science class)

Mark only one oval.

- ☐ ภายในสัปดาห์ที่แล้ว (Within the last week)
- ☐ ภายในสองสัปดาห์ที่แล้ว (Within the last two weeks)
- ☐ ภายในเดือนที่แล้ว (Within the last month)
- ☐ ภายใน 6 เดือนที่แล้ว (Within the last 6 months)
- ☐ ฉันไม่เคยทำการทดลองในวิชาวิทยาศาสตร์ (I have not done any lab into my science class)

12. นักเรียนรู้สึกอย่างไรกับคำถามดังกล่าว (For the following statements, please indicate your feelings of agreement and disagree.)
Mark only one oval per row.

	ไม่เห็นด้วยอย่างยิ่ง (Strong Disagree)	ไม่เห็นด้วย (Disagree)	ปานกลาง (Neutral)	เห็น ด้วย(Agree)	เห็นด้วยอย่างยิ่ง (Strongly Agree)
ฉันทำคะแนนได้ดีใน วิชาวิทยาศาสตร์ (I am able to get a good grade in my science class.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันสามารถทำการ บ้านวิชาวิทยาศาสตร์ ได้อย่างไม่มีข้อสงสัย (I am able to complete my science homework.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีความคิดที่จะทำ อาชีพด้าน วิทยาศาสตร์ใน อนาคต (I plan to use science in my future career.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมุ่งมั่นตั้งใจเรียนใน วิชาวิทยาศาสตร์ (I will work hard in my science classes.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
การที่ฉันทำได้ดีใน วิทยาศาสตร์จะเป็น ประโยชน์สำหรับ อาชีพในอนาคต (If I do well in science classes, it will help me in my future career.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ผู้ปกครองของฉัน อยากให้ฉันทำอาชีพ ด้านวิทยาศาสตร์ (My parents would like it if I choose a science career.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีความสนใจใน อาชีพในสาย วิทยาศาสตร์ (I am interested in careers that use science.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันชอบเรียนวิชา วิทยาศาสตร์ (I like my science class.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีสมาชิกใน ครอบครัวที่ทำงาน ด้านวิทยาศาสตร์ (I know of someone in my family who uses science in their career.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันชอบที่จะพูดคุยกับ คนที่มีความเชี่ยวชาญ ด้านวิทยาศาสตร์ (I would feel comfortable talking to people who work in science careers.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
คุณครูของฉันอธิบาย หลักการทาง วิทยาศาสตร์ได้อย่าง ละเอียดและเข้าใจ (My science instructor explains concepts in a way that I understand)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	ไม่เห็นด้วยอย่างยิ่ง (Strong Disagree)	ไม่เห็นด้วย (Disagree)	ปานกลาง (Neutral)	เห็น ด้วย(Agree)	เห็นด้วยอย่างยิ่ง (Strongly Agree)
คุณครูของฉันทำให้ วิชาวิทยาศาสตร์สนุก และน่าสนใจ (My teacher makes science fun to learn.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Stop filling out this form.

แบบสำรวจการทดลอง (Student Experiment Survey)

คำถามดังกล่าวเกี่ยวข้องกับการเข้าร่วมในห้องปฏิบัติการเคมีของนักเรียน (The following questions ask about your experience participating in chemistry labs.)

13. การทดลองครั้งสุดท้ายของนักเรียนเกี่ยวกับอะไร(What was your last experiment ?)

14. โปรดให้ความเห็นเกี่ยวกับคำถามดังกล่าว (For the following questions please indicate the level in which you agree to the statement.)

Mark only one oval per row.

	ไม่เห็นด้วยอย่างยิ่ง (Strongly Disagree)	ไม่เห็นด้วย (Disagree)	รู้สึกเฉยๆ (Neutral)	เห็นด้วย (Agree)	เห็นด้วยอย่างยิ่ง (Strongly Agree)
ฉันชอบทำการทดลอง นี้ (I liked performing this experiment)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
การทดลองนี้ดูน่า สนใจ (This experiment was interesting to me)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันเรียนรู้ผ่านการ ทดลองนี้ (I learned from the experiment)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันเข้าใจว่าการทำ ทดลองนี้มีความ เกี่ยวข้องกับชีวิต ประจำวัน (I understand how this experiment relates to the real world.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

ความรู้สึกต่อการทดลอง (Emotions Towards Experiment)

อธิบายความรู้สึกที่มีต่อการทดลองในช่องว่าง (For the following word pairs, please fill in the circle between the two given words that best indicates your feelings about the experiment. Use the phrase at the top of each question to begin your sentence).

15. ระหว่างการทดลอง นักเรียนรู้สึก (During this experiment I felt...)

Mark only one oval.

	1	2	3	4	5	
กังวล (Nervous)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	ใจเย็น (Calm)

16. การทดลองเป็นอย่างไร(This experiment was...)

Mark only one oval.

	1	2	3	4	5	
เนื้อหาไม่ครอบคลุม (Incomprehensive)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	เนื้อหาครอบคลุม (Comprehensive)

17. การทดลองเป็นอย่างไร(This experiment was...)

Mark only one oval.

	1	2	3	4	5	
ไม่สนุก (Unpleasant)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	สนุก (Pleasant)

18. ระหว่างการทดลอง นักเรียนรู้สึก (During this experiment I felt...)

Mark only one oval.

	1	2	3	4	5	
น่าเบื่อ (Bored)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	น่าสนใจ (Excited)

19. นักเรียนมีความรู้สึกแบบนี้เพราะเหตุใด (Describe why you gave the answers for the previous questions)

20. การทดลองเป็นอย่างไร(This experiment was...)

Mark only one oval.

	1	2	3	4	5	
ไม่ท้าทาย (Unchallenging)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	ท้าทาย (Challenging)

21. นักเรียนมีความรู้สึกแบบนี้เพราะเหตุใด (Why did you feel this experiment was challenging or unchallenging?)

22. ข้อเสนอแนะเพิ่มเติมสำหรับการทำทดลองเคมีแบบย่อส่วนของโครงการเคมีดาว (Provide any feedback you have to improve the DOW experiments or program)

B2: Student Interview Questions

1. How do you feel about science ?
2. What is your favorite thing about your science class?
3. Do you like doing small-scale experiments?
4. Have you ever experienced a conventional (full) laboratory before? If so, what are some differences, pros and cons.
5. Has your perspective towards science changed before and after you take science class under the DOW program?
6. Does DOW's small-scale make it easier to study and understand scientific concepts taught in class ?
7. If you have chosen your major, what are the factors that influenced you to make that decision
8. If you could change one thing about your science class, what would you change?
9. How often do you study science and how often do teachers perform experiments (schedule, time), are they enough ?

APPENDIX C: TEACHER QUESTIONS

C1: Teacher Survey

แบบสอบถามสำหรับผู้สอนวิชาวิทยาศาสตร์ (Science Teacher Survey)

การยินยอมในการทำแบบสอบถาม (Survey Consent Form)

พวกเราสํานักศึกษาระดับปีที่ 3 จากจุฬาลงกรณ์มหาวิทยาลัยร่วมกับสถาบันเทคนิค (WPI) จากประเทศสหรัฐอเมริกาอยู่ในการดำเนินงานวิจัยภายใต้โครงการเคมีดาว (DOW Chemistry Classroom) ของบริษัท DOW Chemical Company

การเข้าร่วมทำแบบสอบถามจะมีความสำคัญอย่างยิ่งในการพัฒนางานวิจัยของพวกเรานักศึกษา ซึ่งต้องการที่จะเก็บสะสมข้อมูลเกี่ยวกับผู้สอนวิชาวิทยาศาสตร์ โดยผู้ทำแบบสอบถามไม่จำเป็นต้องตอบคำถามทุกข้อ

****ด้วยความที่ข้อมูลนี้จะถูกนำไปใช้สำหรับการวิจัยเท่านั้น ทุกคำตอบจากใบประเมินจะถูกเก็บไว้เป็นความลับและจะไม่ถูกนำไปเผยแพร่อย่างเด็ดขาด****

พวกเรานักศึกษาจากสองสถาบันขอขอบคุณในความร่วมมือตอบคำถามของพวกคุณ

We are a group of students from Worcester Polytechnic Institute in the United States and Chulalongkorn University. We are conducting a study of the DOW Chemistry Classroom's impact on Thai youth interest in science and technology.

Your participation in this five-ten minute survey is voluntary, and you can stop the survey at any point or skip any question. The results of the survey will be completely confidential and no identification information will appear on our published report. The data collected through this survey will be used to guide our published research and allow us to evaluate chemistry education in Thailand.

We would greatly appreciate your participation in our study, but this survey is not mandatory. Ask us any questions if you have them.

1. ฉันสมัครใจในการเข้าร่วมแบบสอบถามครั้งนี้และเข้าใจว่าข้อมูลจะถูกเก็บเป็นความลับ (I understand that my participation in this study is voluntary and confidential.)

Mark only one oval.

- ☐ ใช่ (Yes)
☐ ไม่ (No) Stop filling out this form.

คำถามสำหรับผู้สอนวิชาวิทยาศาสตร์ (Science Teacher Questions)

2. อายุ (Age)

3. เพศ (Gender)

Mark only one oval.

- ☐ หญิง (Female)
☐ ชาย (Male)
☐ Other: _____

4. ระดับการศึกษาสูงสุด (Highest Degree Obtained)

5. ประสบการณ์ในการสอน (Years of Teaching Experience)

Mark only one oval.

- ☐ ต่ำกว่า 1 ปี (Less than a year)
- ☐ 1-2 ปี (1-2 years)
- ☐ 2-5 ปี (2-5 years)
- ☐ 5-10 ปี (5-10 years)
- ☐ 10-20 ปี (10-20 years)
- ☐ มากกว่า 20 ปี (20+ years)

6. ประสบการณ์ในการสอนวิชาเคมี (Years of Chemistry Teaching Experience)

Mark only one oval.

- ☐ ต่ำกว่า 1 ปี (Less than a year)
- ☐ 1-2 ปี (1-2 years)
- ☐ 2-5 ปี (2-5 years)
- ☐ 5-10 ปี (5-10 years)
- ☐ 10-20 ปี (10-20 years)
- ☐ มากกว่า 20 ปี (20+ years)

7. คุณใช้การทดลองเคมีแบบย่อส่วนสำหรับการสอน (Do you use DOW small-scale experiments in your chemistry classroom?)

Mark only one oval.

- ☐ ใช่(Yes)
- ☐ ไม่(No) *After the last question in this section, stop filling out this form.*

8. สิ่งใดสามารถอธิบาย โรงเรียนของคุณได้ดีที่สุด (What best describes your school?)

Mark only one oval.

- ☐ โรงเรียนฉันไม่มีห้องแล็บ (My school does not have a lab)
- ☐ โรงเรียนฉันมีห้องแล็บอย่างเต็มรูปแบบ(My school has a full-scale lab)

9. ชื่อโรงเรียนที่กำลังสอน (School Name)

10. จังหวัด (School Province)

11. ชั้นเรียนที่สอน (Grade Level Taught)

12. จำนวนนักเรียนที่สอนเฉลี่ยต่อห้อง (Average Number of Students per Class)

13. อุปกรณ์ที่ใช้ในการเรียนการสอน (Available Teaching Resources)

Check all that apply.

- ☐ อินเทอร์เน็ต (WIFI)
- ☐ โปรเจ็คเตอร์ (Projector)
- ☐ คอมพิวเตอร์ (Computer)
- ☐ หนังสือเรียน (Textbook)
- ☐ Other: _____

14. วิธีกำจัดของเสียจากการทำทดลอง (Waste Disposal Method Used)

15. ระบบการระบายอากาศในห้องที่ทำทดลอง (Ventilation Method Used)

16. ใส่คำตอบที่สอดคล้องลงในช่องว่าง (Fill in the bubble that corresponds with your answer. Remember that this survey is confidential)

Mark only one oval per row.

	ไม่เห็นด้วยอย่างยิ่ง (Strong Disagree)	ไม่เห็นด้วย (Disagree)	ปานกลาง (Neutral)	เห็นด้วย (Agree)	เห็นด้วยอย่างยิ่ง (Strongly Agree)
ฉันมีอุปกรณ์การสอนที่เหมาะสม (I have the appropriate resources for teaching)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีความมั่นใจในการใช้เทคโนโลยีที่เหมาะสมสำหรับการสอนในห้องเรียน (I feel confident incorporating technology into my lesson plans.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันสามารถตอบคำถามของนักเรียนได้อย่างมั่นใจและถูกต้อง (I can answer my student's questions clearly and correctly.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีความเชี่ยวชาญในวิชาเคมี (I am knowledgeable in chemistry.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันสามารถสอนได้อย่างมีประสิทธิภาพ (I have strong teaching skills.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีพื้นฐานเคมีเพียงพอที่จะสอนนักเรียน (I have proper chemistry background to teach my class).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันมีความมั่นใจในการถ่ายทอดการทดลองให้นักเรียน (I feel comfortable running laboratory experiments in my class room.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

สำหรับผู้สอนที่ผ่านการอบรมของ โครงการเคมีดาว (DOW Training Questions)

17. คุณได้รับการอบรมกับโครงการเคมีดาวมานานเพียงใด (How many years have you been trained by the DOW Chemistry Classroom?)

Mark only one oval.

- ☐ น้อยกว่า 1 ปี (Less than a year)
- ☐ ระหว่าง 1-2 ปี (1 to 2 years)
- ☐ ระหว่าง3-5 ปี (3 to 5 years)
- ☐ มากกว่า5 ปี (More than 5 years)

18. ใส่คำตอบที่สอดคล้องลงในช่องว่าง (Fill in the bubble that corresponds with your answer. Remember that this survey is confidential)
Mark only one oval per row.

	ไม่เห็นด้วยอย่างยิ่ง (Strong Disagree)	ไม่เห็นด้วย (Disagree)	ปานกลาง (Neutral)	เห็นด้วย (Agree)	เห็นด้วยอย่างยิ่ง (Strongly Agree)
ระยะเวลาของการอบรมเพียงพอสำหรับการนำไปสอน (The training was enough time to learn lessons being taught)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันเรียนรู้สิ่งใหม่ๆ จากการอบรม (I learned something new from my DOW training.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
เนื้อหาที่ใช้ในการอบรมมีประโยชน์ (The lessons being taught at the DOW conventions are relevant and useful.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันสามารถถามคำถามขณะอบรม (I felt like I could ask questions if needed at the DOW training.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ฉันสามารถนำการอบรมเคมีแบบย่อส่วนไปสอนในห้องเรียนได้ (I was able to apply the small-scale chemistry lessons to my classroom)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ค่าใช้จ่ายใช้สำหรับการทดลองเคมีแบบย่อส่วนมีความเหมาะสม (The small-scale experiments are cost-effective)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

19. คุณมีความท้าทายในการนำการทดลองแบบย่อส่วนไปใช้ในห้องเรียนไหม (What were some challenges of implementing DOW small-scale experiments into your classroom)

20. คุณรู้สึกว่าทดลองแบบย่อส่วนมีประสิทธิภาพและง่ายต่อการปฏิบัติไหม (Do you feel that the small-scale experiments are efficient and easy to set up?)

21. คุณมีความรู้สึกอย่างไร ก่อนและหลังเข้าร่วมโครงการฝึกอบรมเชิงปฏิบัติการเคมีแบบย่อส่วน (How do you feel about teaching chemistry before versus after DOW training?)

22. คุณคิดว่านักเรียนของคุณชอบการทดลองจากโครงการเคมีดาวหรือไม่ (Do you think that your students like the DOW experiments?)

23. คุณคิดว่าส่วนใดของการฝึกอบรมเป็นประโยชน์มากที่สุด (What did you find most useful about the DOW Chemistry Classroom training?)

24. หากคุณสามารถปรับเปลี่ยนโครงการเคมีดาวได้ คุณจะปรับปรุงอะไร และเพราะเหตุใด (If you could change one thing about the DOW training, what would it be and why?)

C2: Teacher Interview Questions

Initial Questions for School Visits:

1. How do you feel about teaching chemistry before versus after DOW training?
2. Do you think that your students like the DOW experiments?
3. What did you find most useful about the DOW Chemistry Classroom training?
4. If you could change one thing about the DOW training, what would it be and why?
5. What are the differences between teaching in small- scale experiments and full lab facility?
6. Do your students become more interested in science during laboratory class?
7. Do all students get to participate equally in the lab?
8. How long do you usually prepare science experiments?

Revised Questions for Mandarin Hotel Conference

1. How do you feel about teaching chemistry before versus after DOW training?
2. Do you think that your students like the DOW experiments?
3. What did you find most useful about the DOW Chemistry Classroom training?
4. If you could change one thing about the DOW training, what would it be and why?
5. What are the differences between teaching in small- scale experiments and full lab facility?
6. Why do you think you have succeeded in teaching the DOW small-scale experiments?
7. What advice would you give to chemistry teachers who struggle to instruct their teachers in laboratory experiments?
8. Are there any challenges in implementing the DOW SSCL in your classroom? If so, please describe
9. Does the DOW training allow you to learn how the kits are used in certain experiments and how can they be adapted and applied to other experiments?
10. Do you think the SSCL encourages students to pay attention in class and become more interested in science ?

11. What are some factors you believe may influence students' interest in science? (learning environment, teacher, teaching techniques, laboratory experiments etc.)
12. How often do you usually talk or exchange ideas with other teachers under the DOW program?
13. Is there currently adequate access to DOW in case you have any inquiries or are experiencing some issues?
14. If you are uncertain of how experiments are conducted and/or how the kits are used , what do you usually do to solve this problem?

APPENDIX D: ENROLLMENT SURVEY

ข้อมูลการลงทะเบียนเรียนสายวิทยาศาสตร์ (Enrollment Data)

ข้อมูลสำหรับการลงทะเบียนเข้าสายวิทยาศาสตร์ตามแบบแผนของการศึกษาระดับมัธยมปลาย (ม.4 ถึง ม.6) และการศึกษาในระดับมหาวิทยาลัยของนักเรียนจะเป็นข้อมูลที่สำคัญอย่างยิ่งในการพัฒนาวิจัยของพวกเรา นิสิตจากสองสถาบันซึ่งกำลังศึกษาและทำความเข้าใจเกี่ยวกับการใช้การทดลองเคมีแบบย่อส่วนและความสนใจในการเรียนต่อในสายวิทยาศาสตร์ของนักเรียน จึงขอความอนุเคราะห์จากโรงเรียนดังกล่าว ให้ความร่วมมือแก่งานวิจัยของพวกเรา นักศึกษา โดยการส่งข้อมูลเชิงสถิติเกี่ยวกับจำนวนนักเรียนที่ลงทะเบียนเรียนสายวิทยาศาสตร์ในระดับมัธยมปลายและในมหาวิทยาลัย (เฉพาะจำนวนนักเรียนที่เข้าศึกษาในคณะวิทยาศาสตร์) ในระยะเวลา 15 ปีที่ผ่านมา พวกเรานิสิตจากสองสถาบันขอขอบคุณในการให้ความร่วมมือของโรงเรียนดังกล่าว Our team is looking to collect statistics about students enrollment in science over the last few years. We hope to collect data about the number of students who pursued science majors in high school and also the number of students who pursued science majors in university upon graduation. If you have this data, we would greatly appreciate if you could provide it to us. We are looking for trends over the last 15 years, but if you do not have data from then, we would still appreciate if you could upload what you have.

4. หากโรงเรียนมีข้อมูลเกี่ยวกับจำนวนนักเรียนที่ลงทะเบียนเรียนสายวิทยาศาสตร์ ในการศึกษาในระดับมัธยมปลายในรูปแบบไฟล์ สามารถอัปโหลดได้ที่นี่ (If you already have a file that contains science major high school enrollment data, please upload it here.)

Files submitted:

5. หากโรงเรียนมีข้อมูลเกี่ยวกับจำนวนนักเรียนที่ได้เข้าศึกษาในคณะวิทยาศาสตร์ในรูปแบบไฟล์ สามารถอัปโหลดได้ที่นี่ (If you already have a file that contains science major university enrollment data, please upload it here.)

Files submitted:

หากประสบปัญหาในการอัปโหลดไฟล์ โปรดส่งไฟล์มาที่ gr-DOWChem2020@wpi.edu (If you have any trouble uploading your files, please email them to gr-DOWChem2020@wpi.edu)

6. หากได้อัปโหลดไฟล์เสร็จแล้ว จงเลือก "ยืนยันการส่ง" หากมีความต้องการที่ใส่ข้อมูลเอง จงเลือก "ทำต่อ" (If you uploaded a file, select "submit". If you would like to manually input your data press "continue".) Mark only one oval.

☐ ยืนยันการส่ง (Submit) Stop filling out this form.

☐ ทำต่อ(Continue)

การกรอกข้อมูลจำนวนนักเรียนที่ลงทะเบียนเรียนสายวิทยาศาสตร์ตามแบบแผนของการศึกษาระดับมัธยมปลาย Manual Input Enrollment Data (High School Science Major)

หากทางโรงเรียนสะดวกที่จะส่งข้อมูลจากที่ได้กล่าวไว้ ภายในระยะเวลา 15 ปีย้อนหลัง

เพื่อที่จะดูคำนิยามเลือกแผนการเรียนก่อนที่โครงการดาวเคมีจะเกิดขึ้น จะเป็นความกรุณาอย่างยิ่ง (We are hoping to collect data from the last fifteen years but if you do not have that data, we would appreciate if you could submit what you have.)

- [illegible]

29. จำนวนนักเรียนทั้งหมดในชั้น ม. 3 ปี พ.ศ. 2559 (Total number of students enrolled in grade 9 in 2016)

30. จำนวนนักเรียนในชั้น ม. 3 ที่เข้าเรียนสายวิทยาศาสตร์ในปี พ.ศ. 2559 (Total number of students in grade 9 who enrolled in a science major in 2016)

31. จำนวนนักเรียนทั้งหมดในชั้น ม. 3 ปี พ.ศ. 2560 (Total number of students enrolled in grade 9 in 2017)

32. จำนวนนักเรียนในชั้น ม. 3 ที่เข้าเรียนสายวิทยาศาสตร์ในปี พ.ศ. 2560 (Total number of students in grade 9 who enrolled in a science major in 2017)

33. จำนวนนักเรียนทั้งหมดในชั้น ม. 3 ปี พ.ศ. 2561 (Total number of students enrolled in grade 9 in 2018)

34. จำนวนนักเรียนในชั้น ม. 3 ที่เข้าเรียนสายวิทยาศาสตร์ในปี พ.ศ. 2561 (Total number of students in grade 9 who enrolled in a science major in 2018)

35. จำนวนนักเรียนทั้งหมดในชั้น ม. 3 ปี พ.ศ. 2562 (Total number of students enrolled in grade 9 in 2019)

36. จำนวนนักเรียนในชั้น ม. 3 ที่เข้าเรียนสายวิทยาศาสตร์ในปี พ.ศ. 2562 (Total number of students in grade 9 who enrolled in a science major in 2019)

การกรอกข้อมูลจำนวนนักเรียนที่เข้าศึกษาในคณะวิทยาศาสตร์ Manual Input Enrollment Data (University Science Enrollment Data)

หากทางโรงเรียนสะดวกที่จะส่งข้อมูลจากที่ได้กล่าวไว้ ภายในระยะเวลา 15 ปีย้อนหลัง

เพื่อที่จะดูค่านิยมเลือกแผนการเรียนก่อนที่จะโครงการดาวเคมีจะเกิดขึ้น จะเป็นความกรุณาอย่างยิ่ง

We are hoping to collect data from the last fifteen years but if you do not have that data, we would appreciate if you could submit what you have.

37. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2548 (Total number of students enrolled in grade 12 in your school in 2005)

- | | |
|---|---|
| 38. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2548 (Total number of students in grade 12 that enrolled in a science major for university in 2005) | 48. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2553 (Total number of students in grade 12 that enrolled in a science major for university in 2010) |
| 39. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2549 (Total number of students enrolled in grade 12 in your school in 2006) | 49. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2554 (Total number of students enrolled in grade 12 in your school in 2011) |
| 40. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2549 (Total number of students in grade 12 that enrolled in a science major for university in 2006) | 50. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2554 (Total number of students in grade 12 that enrolled in a science major for university in 2011) |
| 41. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2550 (Total number of students enrolled in grade 12 in your school in 2007) | 51. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2555 (Total number of students enrolled in grade 12 in your school in 2012) |
| 42. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2550 (Total number of students in grade 12 that enrolled in a science major for university in 2007) | 52. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2555 (Total number of students in grade 12 that enrolled in a science major for university in 2012) |
| 43. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2551 (Total number of students enrolled in grade 12 in your school in 2008) | 53. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2556 (Total number of students enrolled in grade 12 in your school in 2013) |
| 44. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2551 (Total number of students in grade 12 that enrolled in a science major for university in 2008) | 54. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2556 (Total number of students in grade 12 that enrolled in a science major for university in 2013) |
| 45. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2552 (Total number of students enrolled in grade 12 in your school in 2009) | 55. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2557 (Total number of students enrolled in grade 12 in your school in 2014) |
| 46. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2552 (Total number of students in grade 12 that enrolled in a science major for university in 2009) | 56. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะวิทยาศาสตร์ปี พ.ศ. 2557 (Total number of students in grade 12 that enrolled in a science major for university in 2014) |
| 47. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2553 (Total number of students enrolled in grade 12 in your school in 2010) | 57. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2558 (Total number of students enrolled in grade 12 in your school in 2015) |

58. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะ
วิทยาศาสตร์ ปี พ.ศ. 2558 (Total number of
students in grade 12 that enrolled in a science
major for university in 2015)
-
59. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2559 (Total number
of students enrolled in grade 12 in your school
in 2016)
-
60. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะ
วิทยาศาสตร์ ปี พ.ศ. 2559 (Total number of
students in grade 12 that enrolled in a science
major for university in 2016)
-
61. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2560 (Total number
of students enrolled in grade 12 in your school
in 2017)
-
62. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะ
วิทยาศาสตร์ ปี พ.ศ. 2560 (Total number of
students in grade 12 that enrolled in a science
major for university in 2017)
-
63. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2561 (Total number
of students enrolled in grade 12 in your school
in 2018)
-
64. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะ
วิทยาศาสตร์ ปี พ.ศ. 2561 (Total number of
students in grade 12 that enrolled in a science
major for university in 2018)
-
65. จำนวนนักเรียนในชั้น ม. 6 ปี พ.ศ. 2562 (Total number
of students enrolled in grade 12 in your school
in 2019)
-
66. จำนวนนักเรียนในชั้น ม. 6 ที่กำลังจะเข้าศึกษาในคณะ
วิทยาศาสตร์ ปี พ.ศ. 2562 (Total number of students
in grade 12 that enrolled in a science major for
university in 2019)
-

APPENDIX E: LAB QUALITY SCORING

E1: Criteria for Scoring

Lab Frequency Score: Given based on how frequently students performed chemistry labs in their classroom.

Score of 1: Once a year - Once a Semester

Score of 2: Twice a semester

Score of 3: Once a month

Score of 4: Twice a month- once every other week

Score of 5: Once a week

Lab Group Score: Given based on how many students were in a group when performing experiments.

Score of 1: 7+ students

Score of 2: <7 students

Score of 3: <6 students

Score of 4: <5 students

Score of 5: <4 students

Lab Material Score: Given based on the observed quality and quantity of lab materials.

- Personal opinion based on observation of available lab materials
- Lower scores for schools where students reported lack of materials or broken materials

Overall Lab Quality Score: An average of the three scores above.

E2: Lab Quality Scores for the Schools We Visited

	Frequency of Lab	Frequency Score	Lab Group Size	Lab Group Size Score	DOW, Full, or Both	Lab Materials Score	Lab Quality Score
School 1	1/week	5	4-5 students	3	Both	5	4.33
School 2	DOW 1/week CONV. 2/month	5	5-6 students	3	Both	4	4
School 3	Depends on topic	3	4-5 students	4	Both	3	3.33
School 4	1/semester	1	7 students	1	DOW	1	1
School 5	1/month	3	5 students	3	Non DOW	3	3
School 6	DOW: 1-2/semester CONV: 2/semester	3	5-6 students	3	DOW	5	2.67
School 7	1/semester	1	2 students	5	-Conventional lab in G.10 & G.11 - Only SSCL once in G.12	2	2.67
School 8	1/semester (only G.7)	1	4-5 students	3	Almost no lab	1	1.67

APPENDIX F: STATISTICAL ANALYSIS METHODS AND DEFINITIONS

F1: Two-Sample T-Test Definition

The two-sample t-test is one of the most commonly used hypothesis tests. It is applied to compare whether the average difference between two groups is significant or if it is due instead to random chance. This method of analysis results in a p-value which is the probability of getting the observed difference between the two samples, under the assumption that the population means are equal. Therefore, the smaller the p-value, the stronger the evidence is that the two populations actually have different means. A threshold (known as the significance level) is chosen for the test so researchers can set a boundary to indicate evidence of a difference between the means (StatTrek, 2020).

F2: T-Test Calculations

Definitions of variables: (StatTrek, 2020)

x_A = mean of sample group 1

x_B = mean of sample group 2

sd_A = standard deviation of sample group 1

sd_B= standard deviation of sample group 2

ss_A= sample size of sample group 1

ss_B= sample size of sample group 2

df = degrees of freedom

We first used the following equation to get a t-value:

$$t = \frac{x_A - x_B}{\sqrt{\frac{sd_A^2}{ss_A} + \frac{sd_B^2}{ss_B}}}$$

We then used [Stat Trek t-distribution calculator](#) to compute our probability or p-value. The website had us input our t-value (previously calculated) and the degrees of freedom, which we used the smallest sample size (ss_A or ss_B) minus one.

F2.1: Comparing Interest between non-DOW and DOW

	"I plan to use science in my future career"		"I am interested in careers that use science"		"I like my science class"	
	Non-DOW	DOW	Non-DOW	DOW	Non-DOW	DOW
Mean	3.15	3.57	3.28	3.76	3.46	3.84
STDDEV	1.37	1.00	1.38	0.99	1.07	0.81
Sample	105	148	105	148	105	148
t-value	2.676		3.050		3.068	
probability	0.43%		0.15%		0.14%	
Statistically significant or not	Statistically significant		Statistically significant		Statistically significant	

F3: R² and r Definitions

The r value, or the correlation coefficient, tells us the strength of the correlation between the independent and dependent variable (ex. The strength in the correlation between lab quality score and interest in science). An r value close to 1.0 or -1.0 indicates a strong correlation between the variables. The r value can be positive or negative, which indicates the slope of the regression line and a positive or negative correlation. It is extremely important to note that the correlation described by the r value cannot prove that one variable caused the other (Ganti, 2019). R², or “goodness of fit” of the model, tells us the percent of variance in the dependent variable that can be explained by the independent variable. For the purpose of our analysis, a high R² (~60% and above) value would mean most of the data falls along the regression and the model is a good fit for our data (Corporate Finance Institute Education Incorporated, 2015). To find these values we used excel to give an output of r and R² for each regression line.

F4: Chi Square Test Definition

A chi-square test for independence compares two variables to see if they are related. The test outputs a chi-square statistic and a p-value, or probability. The chi-square statistic compares the expected values with the values you actually collect whereas the p-value takes the chi-square value combined with the degrees of freedom to calculate the probability of the observed result occurring if there was no correlation. The smaller the p-value, the more significant your results are.(<https://www.statisticshowto.datasciencecentral.com/probability-and-statistics/chi-square/>)

To compute these values, we used an online chi-square test calculator:
<https://www.socscistatistics.com/tests/chisquare2/default2.aspx>

F4.1: Chi Square Test for Parent Influence

Chi-Square Calculator

Success! The contingency table below provides the following information: the observed cell totals, (the expected cell totals) and [the chi-square statistic for each cell].

The chi-square statistic, *p*-value and statement of significance appear beneath the table. Blue means you're dealing with dependent variables; red, independent.

	Results					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Row Totals
Strongly Disagree	15 (2.49) [62.72]	6 (3.78) [1.30]	3 (9.97) [4.88]	1 (5.59) [3.77]	2 (5.16) [1.93]	27
Disagree	5 (4.06) [0.22]	16 (6.17) [15.69]	18 (16.25) [0.19]	4 (9.11) [2.86]	1 (8.41) [6.53]	44
Neutral	4 (10.81) [4.29]	17 (16.39) [0.02]	63 (43.22) [9.05]	20 (24.22) [0.74]	13 (22.36) [3.92]	117
Agree	3 (6.46) [1.86]	1 (9.81) [7.91]	23 (25.86) [0.32]	21 (14.49) [2.92]	22 (13.38) [5.56]	70
Strongly Agree	2 (5.17) [1.95]	4 (7.85) [1.89]	9 (20.69) [6.60]	19 (11.59) [4.73]	22 (10.70) [11.93]	56
Column Totals	29	44	116	65	60	314 (Grand Total)

The chi-square statistic is 163.7605. The *p*-value is < 0.00001. The result is significant at *p* < .05.

We used this chi-square calculator to find the statistical significance. The values on the left side of each box indicate the number of responses for that combination of answers. Since this calculator did not allow values of zero, we inputted “1” for the top row, fourth column (Agree, Strongly Disagree). Since we had 313 responses, we assumed that adding one additional response for calculation purposes would not impact our results.

F4.2: Chi Square Test for Self-Efficacy

Chi-Square Calculator

Success! The contingency table below provides the following information: the observed cell totals, (the expected cell totals) and [the chi-square statistic for each cell].

The chi-square statistic, *p*-value and statement of significance appear beneath the table. Blue means you're dealing with dependent variables; red, independent.

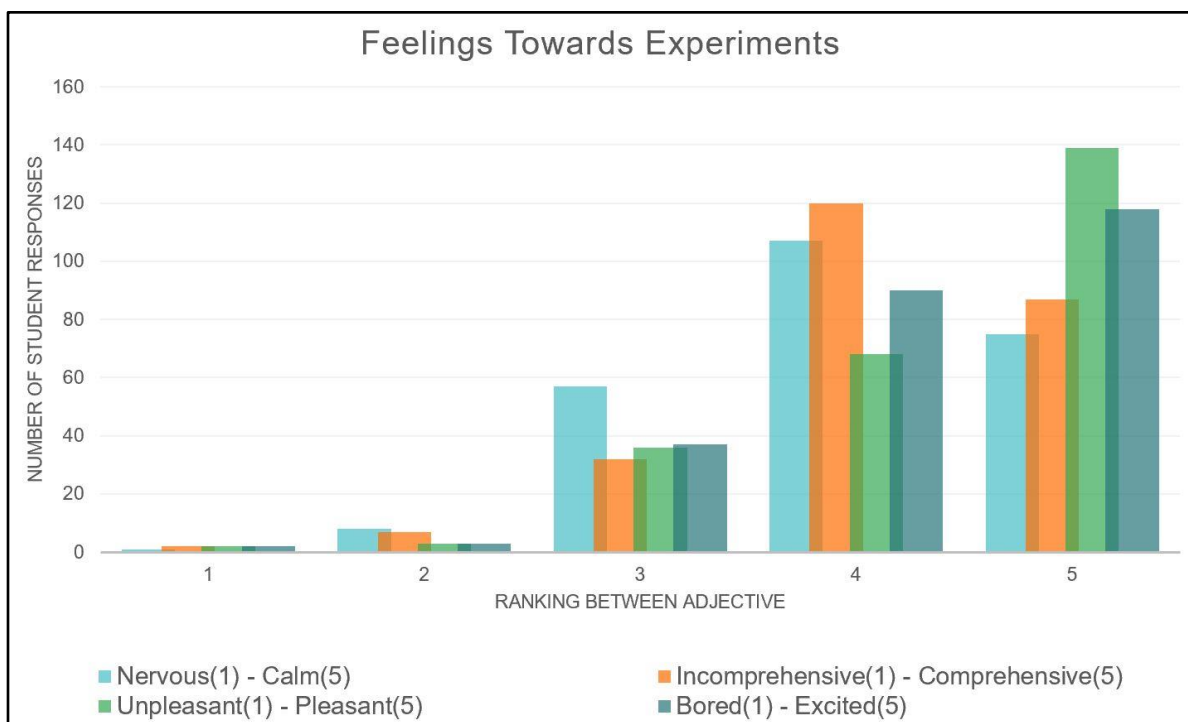
	Results					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Row Totals
Strongly Disagree	2 (0.55) [3.82]	1 (0.84) [0.03]	1 (2.22) [0.67]	1 (1.25) [0.05]	1 (1.14) [0.02]	6
Disagree	6 (1.56) [12.64]	4 (2.37) [1.13]	5 (6.29) [0.27]	1 (3.55) [1.83]	1 (3.23) [1.54]	17
Neutral	17 (13.86) [0.71]	31 (21.03) [4.73]	67 (55.91) [2.20]	25 (31.54) [1.36]	11 (28.67) [10.89]	151
Agree	3 (10.37) [5.24]	7 (15.73) [4.85]	38 (41.84) [0.35]	30 (23.60) [1.73]	35 (21.46) [8.55]	113
Strongly Agree	1 (2.66) [1.04]	1 (4.04) [2.29]	6 (10.74) [2.09]	9 (6.06) [1.43]	12 (5.51) [7.66]	29
Column Totals	29	44	117	66	60	316 (Grand Total)

The chi-square statistic is 77.1013. The *p*-value is < 0.00001. The result is significant at *p* < .05.

We used this chi-square calculator to find the statistical significance. The values on the left side of each box indicate the number of responses for that combination of answers. Since this calculator did not allow values of zero, we inputted “1” for the top row, fourth column (Agree, Strongly Disagree). Since we had 313 responses, we assumed that adding one additional response for calculation purposes would not impact our results.

APPENDIX G: GRAPHS SHOWING DATA TRENDS AND CORRELATIONS

G1: Student's Feelings Towards Experiments



APPENDIX H: FULL SUMMARY OF SURVEY DATA

H1: Teacher Survey

We received 92 responses for our teacher survey. 10 responded “No” to “Do you use DOW small-scale experiments in your chemistry classroom”. Since this wasn’t a large enough group to compare to, we deleted these responses and only analyzed the 82 DOW responses. This is the summary of those 82 responses:

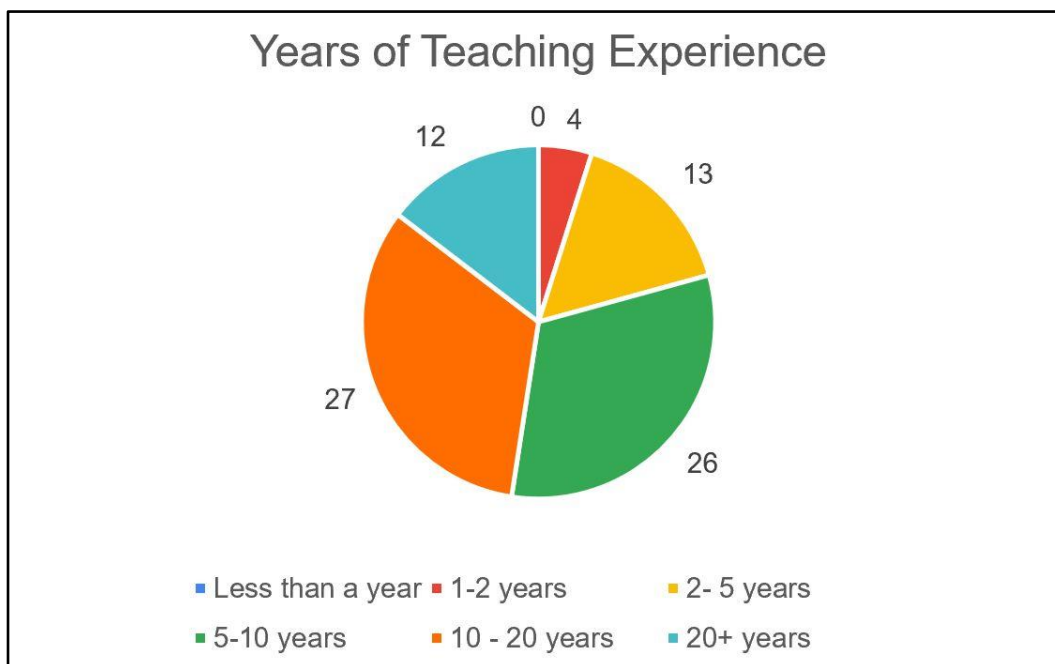
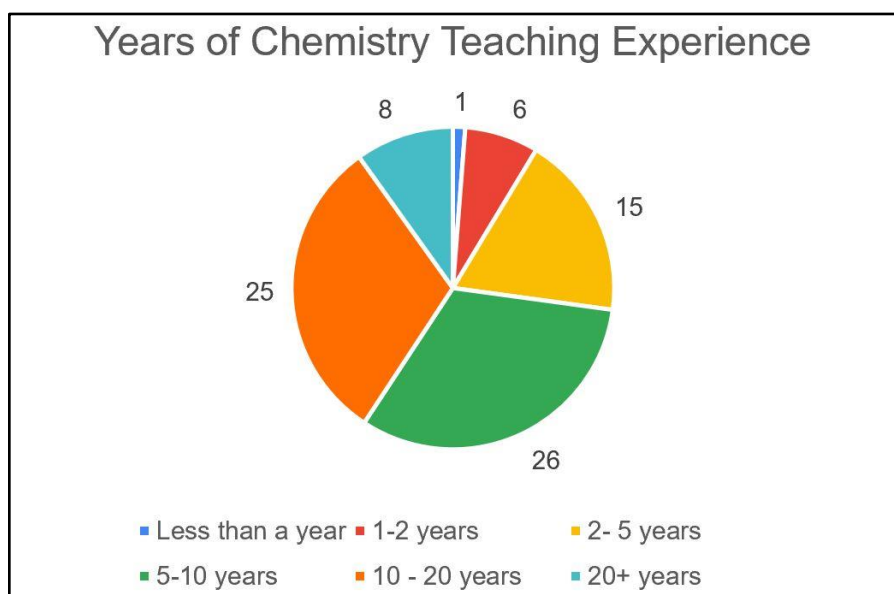
Age:

- Average age: 36.4
- Number of teachers age 20 - 29: 14
- Number of teachers age 30 - 39: 41

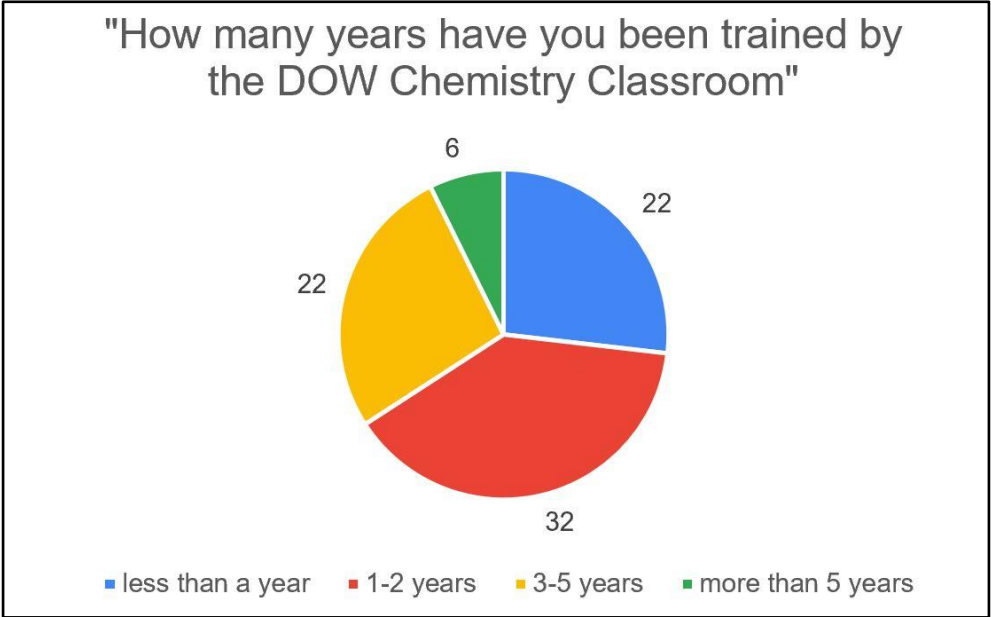
- Number of teachers age 40 - 49: 22
- Number of teachers age 50 - 59: 3
- Number of teachers age 60 - 69: 1

Gender:

- Number of Males: 21
- Number of Females: 61

Years of Teaching Experience:**Years of Chemistry Teaching Experience:**

How many years have you been trained by the DOW Chemistry Classroom



Which best describes your school?

- “Full-scale Lab”: 39 responses
- “No Lab”: 42 responses

Average Number of Students per Class:

- Average number of students: 39.1
- Number of teachers who responded 20 - 29: 6
- Number of teachers who responded 30 - 39: 26
- Number of teachers who responded 40 - 49: 40
- Number of teachers who responded 50 - 59: 7
- Number of teachers who responded 60 - 69: 2

Strongly Disagree to Strongly Agree Questions:

Statement	# of Strongly Disagree	# of Disagree	# of Neutral	# of Agree	# of Strongly Agree
I have the appropriate resources for teaching	8	8	28	33	5
I feel confident incorporating technology into my lesson plans	7	6	18	35	16
I can answer my students’ questions clearly and correctly	6	3	14	33	25

I am knowledgeable in chemistry	8	4	15	38	16
I have strong teaching skills	6	3	15	42	15
I have the proper chemistry background to teach my class	7	3	10	40	21
I feel comfortable running laboratory experiments in my classroom	8	3	14	33	23
The training was enough time to learn the lessons being taught	3	3	19	43	13
I learned something new from my DOW training	3	1	6	30	41
The lessons being taught at the DOW conventions are relevant and useful	3	1	4	36	37
I felt like I could ask questions if needed at the DOW training	3	1	12	41	23
I was able to apply the small-scale chemistry lessons to my classroom	3	2	7	39	31
The small-scale experiments are cost-effective	1	4	14	42	20

What were some of the challenges of implementing DOW small-scale experiments:

About organic experiment
Attracting kids' interest (สามารถกระตุ้นความสนใจได้ดี)
Attracting lots of kids, Improve their understanding.(กระตุ้นความสนใจให้นักเรียนทำได้ความรู้จากการทดลองเป็นอย่างดี)
Because only some DOW's lab match with science cirriculum (มีการใช้การทดลองย่อยส่วนที่ตรงกับเนื้อหาการเรียนได้เป็นบางการทดลอง)
Buy equipment
Creating methods
Developing material for the small-scale lab (มีความท้าทายในการออกแบบการทดลองโดยใช้อุปกรณ์และสารเคมีที่พอจะหาได้ง่ายในโรงเรียน)
Developing the suitable lab for kids with safety and consume less time. (ท้าทายในการออกแบบการทดลองที่อยู่ในหลักสูตรที่เรียนและส่งผลดีต่อผู้เรียนทั้งระยะเวลาที่เหมาะสม เห็นผลชัดเจน การทดลองมีความปลอดภัยสูง)
Enthusiasm in teaching (กระตือรือร้นในการสอน)
Galvanic cell experiment is tough.(มีความท้าทายในเรื่อง galvanic cell)
Have
Have
Have
Have

[illegible]

Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes, about the equiment condition (มี คืออุปกรณ์จะทดลองได้ใหม่)
Yes, as it requires less chemical, less time, etc. (มีความท้าทายมาก เพราะถือว่าเป็นเทคนิคใหม่ที่ทำงาน ใช้สารน้อย เห็นผล)
Yes, because students are monk.(ใช่เพราะกลุ่มตัวอย่างเป็นสามเณร)
Yes, for the classroom development.(สามารถนำไปพัฒนา ใช้ในห้องเรียนได้)
Yes, interesting (มีความท้าทายและน่าสนใจ)
Yes, It does
Yes, it does
Yes, most of the time (มีมากค่ะ)
Yes, small-scale experiment gives same result as normal-scale experiment and give even better picture. (มีความท้าทาย ซึ่งการทดลองเคมีแบบย่อส่วนทำให้นักเรียนตื่นเต้น เพราะเห็นผลชัดเจน และได้ผลการทดลองเร็ว)
Yes, students will get to know more...lab gadget is easily to find.(เด็กได้เรียนรู้มากขึ้น..หาอุปกรณ์ง่าย ๆ)
Yes, there are some challenges

Do you feel that the small-scale experiments are efficient and easy to set up?

yes, it can be as effective as the conventional lab. Can be use more often in classroom, no need to always do full lab
convinient and applicable in real life
convinient and can be applied in teaching
convinient and easy to understand
convinient and gives overall picture of the concept
Easy
easy
Easy
easy
Easy
easy
easy
easy
Easy
easy
easy

easy and effective
easy and effective
easy and effective
easy and effective
Easy and effective but there were some errors in analytical lab
easy and give a better picture
Easy in some experiments
Easy in some experiments
easy to conduct
easy to conduct
easy to conduct
easy to conduct
easy to conduct and results are obvious and observable
easy to conduct if there is sufficient equipment
effective
effective
Effective
effective and easy to conduct
effective and easy to conduct
effective and easy to conduct
effective, observable, and applical in classrooms
good
I feel so good
It is difficult to set up
It's easy but we need to create by our own technique.
more efficient in designing experiments
the experiments are very effective
useful for both teachers and students
very effective, safe, and convinient
very good
Yes
Yes
Yes
Yes
yes
yes
Yes
yes
Yes
Yes
Yes
yes
Yes
yes
Yes

yes
Yes
Yes
Yes
Yes
yes
Yes
Yes
yes but not all the experiments
Yes I do
Yes of corse
Yes they could manage the training time very well
Yes, but in some labs are not in accordance with the purpose of the training.(รู้สึกเช่นนั้น แต่บางกิจกรรมอาจไม่สอดคล้องกับจุดประสงค์ของหลักสูตรที่บางหัวข้อต้องการให้เรียนรู้ผ่านอุปกรณ์)
Yes, i do
Yes, i do

How do you feel about teaching chemistry before versus after DOW small-scale training?

Before, I wasn't confident with performing experiment, but the training allows me to carry out and explane it correctly
Before the trainig, I had no clue what small-scale experiment was, but after getting to know the SSCL, I really like because it allows kids to understand, at the same time, teachers can perform experient in a shorttr period of time.
Before the training, I felt the conventional lab was boring, requires large amount of chemicals and many equipments, which isn't enough for all the students. After the trainig, doing seems easier, kids can actually observe the reaction, and learing science becomes more interesting
improve creativity in creating teaching resources, using equipments, and method to carry out experiment
new techniques, perspective, and a chance to exchange ideas with teachers from different countries
recieve more experience from the trainig, opportunity to exchange thoughts with teachers from other school, new perspectives on how to use and adapt the equipments
After the trainig, I gained a lot of useful knowledge.
After the training, I recieved more useful knowledge
always impressed and happy to participate
Amazed when students can actually understand by performimg SSCL
At this time, i feel i have movative and energy
Before the training, I struggled with many experiments, but after I know how the issues ca be solved. Students can perform experiment with SSCL, making it more convinient

Before, I didn't know how to use SSCL equipment, but after the training I gained more knowledge and can implement it appropriately
Better
can be adapted and applied
convenient and affordable
curious, interested, and excited to apply in classroom
Dow small-scale training makes me more confidence in teaching chemistry
DOW small-scale training making experiment easy, low cost and save
Easy then before
easy to understand, very useful for teaching in classroom
Enjoy teaching science using Small-Scale equipments
excited and curious
Excited in bringing new ideas to the classroom
excited to use and apply in classroom
exciting
experiments are easier to prepare and carry out
feels good, gained new experience
feels good
feels good
fun
good and looking forward to deliver these to the students
Got many new ideas about small-scale experiment
Got new ideas to adapt the experiments
Got so many interesting ideas
I feel excited
I feel excited
I feel good
I feel like get exposure to chemical and waste chemical substance to used.
I feel so glad to join this conference because it's the good technique to improve the chemistry experiment in high school level to the students.
I feel so glad to join this conference because it's the good technique to improve the chemistry experiment in high school level to the students.
I got to learn about experiments, which will make teaching easier.
I used to feel like performing experiment was difficult, but the training gave me confidence and made experiments easier to carry out.
Impressed and the knowledge is practical in teaching students
impressed because it can be used in real life
improve our chemistry experiment
It is hard but after training it is easy for me
Its very efficient
Like it because it improve my skills and knowledge
Make laboratory class easier
More capable of designing new experiments
more confidence
more confident in preparing and conducting experiments

more knowledgeable on how to apply SSCL into teaching
more knowledge
more knowledge
New ideas on how to perform SSCL in related topics
New knowledge, can apply to students in the class.
New network across ASEAN(ได้มีเครือข่ายในอาเซียน)
not as complicated as thought
observable and requires minimal chemicals
Praktikum more effective and efficient
receive knowledge and teaching techniques to apply with small-scale kits
receive knowledge and experience
save time and more affordable
SSCL is very useful, it is very practical. However, in some experiments such as titration, the conventional lab is still necessary.
useful
very fun
very good
very good
Very good in training. It gave the teachers ideas to improve and design the experiments in class
very good, enjoyable
very interesting and after the training, I can apply this knowledge and techniques in teaching
very useful, should happen regularly
Wonderful

Do you think that your students like small-scale experiments?

[illegible]

Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like
Like all the hands-on experiment
Like because everyone gets to participate
Like because it requires less chemicals
Like doing experiments more
Like it if they can adapt it to their daily liives
Neutral
not sure, but it is very useful
probably yes
Some of them are more interested
The students like it because they get to do individually
The students really like the experiments
They like it
They like it
They like it
They like it
They like it
They like it
They like it because it's challenging and the kids could focus more on doing experiments
They like it because it's convenient and some equipments were too simple but unexpected
They like it because it's less time consuming and easy to understand
They like it because it's not boring and environmental friendly
They like it because the results gave a clearer picture
They really lilke it
Yas I do
Yes
Yes
Yes
Yes
Yes
Yes

yes
yes
Yes
yes
Yes
Yes it is
Yes of course! They really like it.
Yes of course! They really like it.
Yes, and the kids become more interested in science
yes, because it is observable
Yes, i do
Yes, i do
Yes, i do
Yes, I do because it gave the students opportunity to do hands-on experiment
Yes, they like to study to make experiments

What did you find most useful about the DOW training?

1.less chemicals required 2.equipments can be easily found 3. students can understand concepts more easily
Applying local natural resources(save money!)
(การประยุกต์ใช้อุปกรณ์ที่หาง่ายในห้องอื่น ไม่ต้องพึ่งอุปกรณ์ราคาแพง)
connections with other teachers
Create new innovation in class(ความคิดสร้างสรรค์และการผลิตนวัตกรรมในห้องเรียน)
demonstrating science experiments
Demonstration of experiment(การลงมือปฏิบัติ และมีการให้ตัวอย่าง demo มาทดลอง)
Doing experiement (การทดลอง)
Dow Chemistry Acadamy
Dow training is mostly useful. It's can help me to do the experiment to my students and help save environment pollution when we waste it.
Dow training is mostly useful. It's can help me to do the experiment to my students and help save environment pollution when we waste it.
Easy to do experiments
Electrochemistry(ไฟฟ้าเคมี)
Equipments are easily prepared, doesn't require lab
expeirments can be carried out in classroom
experience to doexperiment
Experiment
experiment
experiment
experiment, because it gives us technique that allows us to teach the students
experiments used in teaching

Fun, easily to understand
Gain idea for developing new experiment (ได้แนวคิด ในการนำไปใช้ออกแบบการทดลอง)
Gain knowledge about small-scale experiments
Gets idea from PACCON event(ศึกษาดูงาน Paccon
ได้เปิดโลกการทดลองใหม่ๆจำนวนมาก เห็นถึงโอเดียการทดลองต่างๆ)
hands-on experience
hands-on experience
hands-on experience on several experiments
how to perform experiments
I have some ways to apply in my classes
I know lots of experiment chemistry
Ideas to make kit
Keep environment clean and safety
kids get to perform experiment thoroughly
Lab
Lab(การทดลองทำปฏิบัติการ)
Lab(ทำปฏิบัติการ)
Learn new experiment, exchange idea with other
teachers(ได้เรียนรู้เทคนิคการทดลองเพิ่มมากขึ้น
ได้เสวนากับเพื่อนครูทั้งในประเทศและต่างประเทศ)
learn new techniques
Learn to conduct experiment in more effective ways
Learning by the role-model teacher
Learning by the role-model teacher
Less chemicals are used
Less chemicals are used
Lots
Lots (มากที่สุด)
Low cost, easy to doing experiment and safety
More experience and knowledge
More savety
New experiment for future development(การนำเสนอการทดลองใหม่ๆ
ทำให้มีแนวคิดเพื่อพัฒนาต่อไป)
New experimental kits
new lab experiments
New way of thinking(แนวคิดใหม่ๆ ในการทดลองที่ให้ความหลากหลายของวิธีคิด
หลากหลายคำตอบที่ถูกต้องมากกว่าการทดลองที่นำไปสู่คำตอบหรือข้อสรุปเดียว)
performing experiment and connect scientific concepts to it
performing experiments
performing experiments with teachers from different countries
Practical learning(ได้ทดลองปฏิบัติการทดลองจริง)
Practical learning(การลงมือปฏิบัติจริง)
Save money and interesting experiment

Seeing forienger perspective through workshop(ส่วนการ workshop โดยวิทยากรชาวต่างชาติ เนื่องจากได้มุมมองที่ต่างออกไป)
Small and affordable
Small-scale can be easier to understandเทคนิคการทำทดลองที่ในบางครั้งเราทำตามหนังสือเรียนมากเกินไป แต่ แบบย่อส่วนทำให้เข้าใจไม่ยุ่งยาก
The experiment is easy to apply in my class and i can solve the problem when i apply SSC
The experiment is easy to apply in my class and i can solve the problem when i apply SSC
To cut down the pollution, save money ,save time
Traing in school by the expert(การฝึกอบรมกับวิทยากรที่มีประสบการณ์ การสาธิตใน ร.ร. และการเป็นวิทยากร)
Using cheap instrument (การเลือกใช้วัสดุที่หาง่ายๆแทนวัสดุอุปกรณ์ที่ราคาแพง)
We can do our experiments with our surrounding materials workshop
yes
YES

If you could change one thing about the DOW training, what would it be and why?

Adapting instrument for middle high school student.ปรับชุดการทดลองให้เข้ากับการเรียนวิทยาศาสตร์ ม.ต้น
adapts for primary school students.
Advertisment(ประชาสัมพันธ์หลายๆช่องทาง)
After the conference, making a teacching competition for teacher(Use small- scale equiment) (หลังครุอบรม จัดประกวด การจัดการสอนโดยใช้อุปกรณ์จากเคมีดาวหรือพัฒนาใหม่ให้สอดคล้องกับหลักสูตร ในแต่ละระดับเช่นประถม มัธยมต้น มัธยมปลาย จะได้เห็นผลชัดเจน ครูนำวิธีสอนนี้ไปเป็นส่วนประกอบในการพัฒนาตนเองในสถาบันได้ด้วย(เป็นผลงานครู)จะทำให้ครู เห็นความสำคัญ ได้ขยายผลต่อยอดไปได้ยาวนาน ส่วนปัจจุบัน dow-cst ก็คงไว้)
All Good !(โครงการนี้ดีและเหมาะสมแล้วค่ะ)
All small-scale kits should be in good conditions.ปรับการสร้างอุปกรณ์ให้ใช้งานได้มีคุณภาพมากขึ้น เพราะเวลามาอบรมเครื่องมือบางอย่าง ยังใช้ได้ไม่ดีพอ มีรื้อ มีไม่สมบูรณ์บ้าง
Creates more new lab(มีช่วงของการช่วยกันออกแบบการทดลอง)
Develops new handbook (พัฒนาคู่มือครู)
Give me more time
Good
I Hope this training doing more on Indonesia

I think Dow training should provide some kits to teacher in ASEAN to teaches other students
I want buying small-scale equiment to be easier (การติดต่อซื้ออุปกรณ์เคมีดาวให้ง่ายต่อการซื้อมากขึ้น)
I want DOW to make at least 5 new labs and introduce it to schools.(อยากให้จัดอบรม มีกิจกรรมให้ทำแลบ ใหม่อย่างน้อย 5 การทดลอง และมีออกไปตามโรงเรียน
I want DOW-CST contest in Thailand and aboard. (ให้มีการนำเสนอการทดลองที่หลากหลายมากยิ่งขึ้นทั้งงานที่ถูกสร้างขึ้นทั้งในและต่างประเทศเพื่อให้เกิดไอเดียที่จะนำไปต่อยอด)
I want more outstanding teacher to share their knowledge in train the trainer. (เห็นถึงความตั้งใจการพัฒนาทั้งครูและนักเรียนในด้านต่างๆ มีโครงการ training the trainer ในการฝากคุณครูที่เป็นครุต้นแบบในการขยายผลยังโครงการที่อยู่แล้ว)
I want more small-scale kits for my kids.(อยากให้มีการจัดให้ใช้ชุดการทดลองให้เยอะกว่านี้ เพื่อให้เห็นการนำไปใช้งานมากขึ้น)
I want take my students to travel and do workshop oversea.(อยากให้นักเรียนได้มีโอกาสแลกเปลี่ยนกับนักเรียนจากหลายๆประเทศเหมือนคุณครูบ้าง)
I want to have more training which in accordance with IPST(การอบรมให้มีเพิ่มมากขึ้นและเพิ่มการทดลองเคมีแบบย่อส่วนให้สอดคล้องกับเนื้อหาใน สสวท.)
I want to share experience.(อยากให้มีการแชร์ ประสบการณ์ กันมากกว่านี้)
Improve the experiment activity(เพิ่มกิจกรรมทดลอง เวลาการทดลอง)
Involving the students, because some of them lack of laboratory skills
It is good. I want DOW to give us more financial support.(เป็นโครงการที่ดีมาก อาจขยายเพิ่มในเครือข่าย สนับสนุนงบในการอบรมครูในแต่ละจังหวัดต่อไป)
It's perfect !
Keeping chemical solution instrument (อุปกรณ์บางอย่างในการเก็บสารละลาย)
Makes a platform for buying small-scale kit(ทำเครือข่ายชุดปฏิบัติการย่อส่วน)
Makes more suitable instrument(ชุดอุปกรณ์ให้สอดคล้องกับหลักสูตรในบทเรียน)
Making small-scale for other subjects(นำไปประยุกต์ใช้กับรายวิชาอื่น)
More opportunities to do all experiments, more time so there is no need to hurry
No
No idea
No idea
No idea
No! Thanks
Nope
NOPE !!!
Nothing
Nothing
Ok

Organization of DOW-CST competition(รูปแบบการจัดการแข่งขันเคมีดาว)
Perfect !(ดีแล้วครับ ขอขอบคุณโอกาสและประสบการณ์ให้ให้มาร่วมพัฒนาดนเองร่วมกันครับ)
Perspective !(ปรับทัศนคติ)
Presentation of ASEAN teacher(การนำเสนอของครูในชาติอาเซียน)
Sends handbook to the involved school.(ปรับเคมียอส่วนให้มีทุกเรื่องในหนังสือเรียนพร้อมจัดส่งสื่อฟรีให้รร.ที่เข้าร่วมโครงการ)
Seperates primary school and high school lab(การแยกอบรมครูผู้สอนระดับประถมศึกษาและมัธยมศึกษาเพราะจะได้เนื้อหาเหมาะสมกับผู้เรียน ซึ่งส่งผลต่อการนำมาใช้ประโยชน์ได้จริง)
Students often confuse with the lab so maybe DOW should adpat the order of lab procedure.(ลำดับขั้นตอนในการทำการทดลอง เมื่อนักเรียนบงมือปฏิบัติแล้ว เกิดความสับสน ไม่สามารถอ่านและลงมือปฏิบัติได้ด้วยตนเอง)
The procedure of experiments. Some people make the water dirty
The procedure of experiments. Some people make the water dirty
Wants experiement that in accordance with classroom topic(อยากได้การทดลองที่ใช้ในวิชาเรียน)
Wants experiement that in accordance with classroom topic, Currently, only some experiment are usable(อยากให้ใช้การทดลองที่เป็นของหลักสูตรร่วมกันไปด้วย ให้ครอบคลุม แต่ในปัจจุบันคือใช้ได้กับบางระดับชั้น)
wants small-scale for primary school !(การทดลองที่น่าสนใจกับนักเรียนชั้นประถมศึกษา)
wants small-scale in countryside(อยากให้มีการจัดต่างจังหวัด)
Wants teacher to exchange the lab experience(อยากให้ครูมีการแลกเปลี่ยนในการทำ lab มากขึ้น)

APPENDIX I: SUMMARY OF INTERVIEW DATA

II: Summary of Interviews at DOW-CST Awards

Experiments from DOW-CST Contest

Experiment 1



Description of Experiment created:

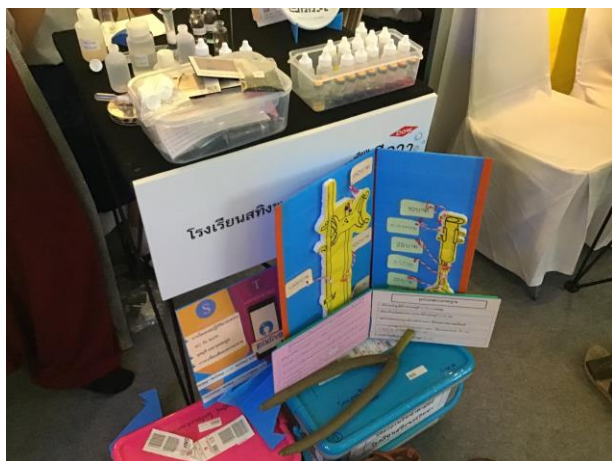
An unpleasant odour created from spoilage of food waste in the school canteen has been a long standing issue for everybody, especially the students. As a result, the students are committed to finding a solution to eliminate those odors by using plants in their local community. Three samples used were Banana Stalk, Pandan, and Feather Pennisetum. The difference between pores size allows them to conclude Feather Pennisetum to be the most effective, due to its highest ability to absorb oil and odors. In order to make the absorbent sheets, the plants were grinded into fine mixture, shaped into thin sheets, dried, and compressed.

Interview responses:

The students from Buntharikwittayakarn School (Ubon Ratchathani Province)) reported DOW Chemistry Classroom gives them the opportunity to spend their time wisely. Additionally, the hands-on experience motivates them to become more interested in science. Moreover, the teacher mentioned students' participation also increases when experiments are carried out as a group.



Experiment 2

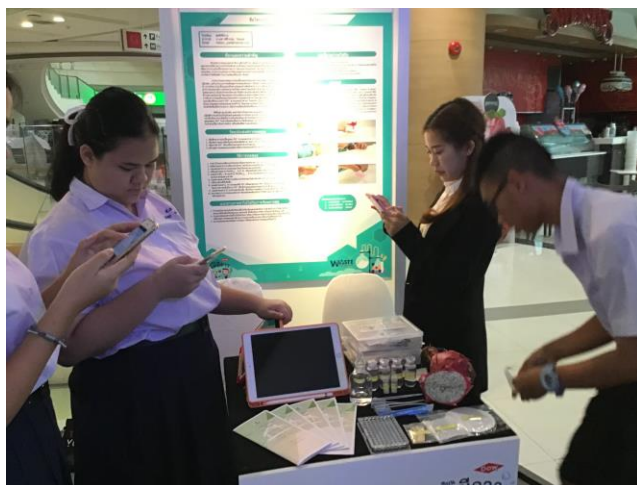


Description of Experiment created: Micro-scale titration techniques & Synthesis of Acid using local plants.

Interview responses:

- Group of 3-4 students (grade 10)
- From Sathing Phra Wittaya (Songkhla province)
- Used to have no lab before DOW classroom was implemented
- DOW chemistry classroom provides a chance for them to use local resources wisely

Experiment 3



Description of Experiment created:

Finding lead(Pb) contamination in natural water using Pitaya.

Interview responses:

- Group of 5 students (grade 10)
- From Stristrinan School (Nan providence)
- Used to have no lab before DOW classroom was implemented
- Pitaya is not just fruit! It can be used for pollution leak indication ex. Pb^{2+} ion in contaminated water

Experiment 4



Description of Experiment created: Separation of various Ion using filtered paper.

Interview responses:

- Used to have full lab but lacks some lab resources
- SS lab easier to understand compared to normal lab

Experiment 5



Description of Experiment created: Water Treatment using electrocoagulation method with aluminum electrode

Interview responses:

- Group of 5 students (grade 10)
- From Strisrinan School (Nan providence)
- Used to have No lab before DOW classroom implemented
- Widely used techniques for water treatment process (aqueous medium)

Experiment 6



Description of Experiment created:

The students came up with an innovation to remove toxic chemicals from dye before water can be drained and disposed of. The dye in water is removed and absorbed as it passes through layers of cotton, sand, charcoal powder, White Rot fungi. The White Rot Fungi produces enzyme which activates the whole process.

Interview responses:

The teacher stated small-scale experiments allow students to learn how equipments are handled. It generates less waste and requires less time. In comparison, the conventional lab normally requires at least 2 hours to prepare and carry out, while the small-scale allows learners to understand the concept within a shorter period of time.

Experiment 7





Description of Experiment created:

The students came up with an idea to purify water and soil that are contaminated heavy metals using a process called Phytoremediation. Phytoremediation can be understood as the use of plants (trees, shrubs, grasses and aquatic plants) and their associated microorganisms in order to remove, degrade or isolate toxic substances from the environment.

Interview responses:

The teacher mentioned the kids enjoyed learning science with hands-on experience. They pay more attention in class and are also enthusiastic to invent new experiments and join the CST competition.

Experiment 8

Description of Experiment created: Microplastic Management

Translation of interview and questions asked:

- Grade 9 students
- From Prachinburi province
- 1st time small-scale lab implemented
- Normally had no lab at school
- Usually implement the lab in lecture classroom in a group of 5 students

Teacher Interview at DOW-CST Awards:

1. He feels happy DOW gives him a chance to create new science experiments that can be applied to solve current environmental problems
2. He likes the DOW Program because of its small size so he can perform the teaching experiments wherever he wants. The
3. He loves to talk and exchange useful ideas with the foreign instructors
4. He couldn't think of any other ways to improve the program . DOW already adapted the classroom as the theme of this year is about water reduction.
5. He believes students need both styles of labs, small-scale and full-scale because most of the universities in Thailand teach using a full-scale lab.
6. One suggestion to improve the competition was to increase the promotion of small-scale so there are more participants in the competition.

I2: Summary of Student Interview Responses

School Number	Compiled Key Responses from Student Interviews
1	<ul style="list-style-type: none">● They find small-scale lab convenient, require less time and solvents and allows them to understand scientific concepts better.● Some drawbacks are they are less noticeable and students may have difficulty understanding how conventional lab equipment are handled.● Enjoy and would love to do more experiments● “It’s more interesting than learning theory because I get to see what is happening in real-life. I want to do small-scale for the whole year”● It gives me a hands-on experience● Noticed high interest in science● “Some lab rooms are for storage only so we usually perform small-scale lab in our classrooms”
2	<ul style="list-style-type: none">● Enjoy hands-on experiment● Can feel the environment and learn something new● Like small-scale because saves time and is easy● Experiments allows them visually to understand the topics● They reported SSCLs are convenient, fast, applicable, since materials can be easily found and adapted.● For instance, using wooden popsicle sticks to stir solutions.● One student mentioned her parents forced her to do science major, when she actually prefers art.● Have 3 science classes/week and lab class 2-3 times/month
3	<ul style="list-style-type: none">● They are interested in science because they can observe the surroundings.● Some students love science because of the practical learning● Small-scale help improving the understanding of science● Small-scale is a good choice but a big lab gives a better picture of what is going on.● Students would prefer to have more practical learning and experiments● Students enjoy the experiments because they enjoy preparing chemicals

	<p>and seeing results, makes them excited</p> <ul style="list-style-type: none"> ● <i>Full-scale lab</i>: Everything is a lot, there are a lot of instruments. I get more concerned when I do full-scale since there is so much to prepare and there is also a lot of equipment to dispose of and wash, 50 minutes. Overall, I get a little anxious. Takes a long time to prepare and clean ● <i>Small-Scale lab</i>: it's easier and there is less lab equipment. It's more concise and fast (around 10 minutes). It's more interesting because I have to always focus on what's going to happen. Overall, it's more friendly ● Small-scale allows students to perform rather than watching teacher perform a large scale experiment
4	<ul style="list-style-type: none"> ● One kit box per 6-7 persons. ● Small-scale labs give them a better understanding of science. ● Enjoy science because of experiments ● Before using DOW, students had no practical learning. ● Experiments make them excited to learn ● Only one science teacher, limited science education quality ● Many students pursuing non-science major due to background
5	<ul style="list-style-type: none"> ● Performs experiment 2-3 times per semester depending on their topic of study. ● Equipments are broken and insufficient ● We found teacher also plays impact on students' interest and understanding ● Majority selected science major due to more options in future career ● One of the experiments done was titration
6	<ul style="list-style-type: none"> ● Frequency of experiments <ul style="list-style-type: none"> ○ DOW 1-2/semester ○ Full-scale 2/semester ● Students reported too much theory were taught, while only little experiments ● Enjoy chemistry the least out of three branches of science. ● Some kids prefer to do full-scale lab because it gives a clearer result and requires less time.

	<ul style="list-style-type: none"> ● Their favorite experiment was flame color and spectrum elemental using bunsen burner
7	<ul style="list-style-type: none"> ● Would like to do less theory and more experiments (both SSCL and Full-Scale lab.) ● Having the opportunity to do labs allows them to understand science concepts better. ● Small-scale can save more time, easy to use ● After DOW's experiment, students feel more interested in science ● Not enough time for students to perform hands-on experiment in G.12 ● Large class size of 45, teacher can't pay attention to everybody ● Incomplete, broken old equipments ● One student reported she prefers arts, but was influenced by her parents to study science major due to more options in future career. ● Chemistry classes are taught 3 sessions/week, but they have done the small-scale once, which is not enough and they would love to do more. ● If there's something they could change, they would want to perform more hand-on experiments.
8	<ul style="list-style-type: none"> ● They do not have any major. Normally, the school focused on buddhism. ● Before, no lab class ● They did small-scale and they found out that small-scale is super comfortable as its size. ● Small-scale gives a better picture for understanding. Before doing small labs were confused. ● Small-scale gives a better picture for understanding. ● Only one lab per semester (Grade 7). Would like to have more practical learning in science

I3: Summary of Teacher Interview Responses from School Visits

School Number	Compiled Key Responses from Teacher Interviews
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1	<ul style="list-style-type: none"> ● Teaches small-scale to multiple classes in grade 11 ● Feels that using SSCL is very convenient and useful since less chemicals are required, less danger, reduce chemical waste, and it takes less time to do lab set up ● <u>Before SSCL</u>: requires a lot of chemicals and set up, and not all students get to use real instruments since they're expensive, tired and difficult to do waste disposal. They have no lab assistant so some teachers just skip lab sessions and rely on "Dry lab" and theory instead due to time limitations ● <u>SSCL</u>: more convenient, they are organized into smaller baskets (EX: 100 ml of chemicals can be used 3-4 times), and they don't have to take care of the equipment. Some instruments can be used to teach different lab topics (science teacher improvises and come up with new lab topics based on what they have in their lab kits) ● All students like to do experiment since they understand more ● Believes that small-scale provides more conceptual understanding than full-scale lab
2	<ul style="list-style-type: none"> ● I don't use sscl 100% because some science topics cannot use small-scale ● My topics have to be based on the IPST standard curriculum which provides topic content as long as laboratory experiment so I decided to combine this with sscl ● Advantage: on budget ● Decide Full-scale vs SSCL: Quantitative vs. Qualitative <ul style="list-style-type: none"> ○ Qualitative lab requires instrumentation and amount so they should be taught in full-lab scale ○ Quantitative lab is for analyzing chemical substances so SSCL is preferred. Students also like it more since it requires less time and it's easier and it's way more concise than full-scale ● I prefer that both of these two types of laboratories be taught together since you cannot replace one by the another ● I like to be a science instructor since I get to share my knowledge in small-scale to other science teachers that don't have the opportunity to attend DCC ● I also like PACCON event where i get to learn a few more SSCL lab topics

	<ul style="list-style-type: none"> ● Doesn't buy all kit boxes but he comes up with a new science topic based on the small-scale concept ● Taught in 2 periods (100 minutes in total)- (1 week teach 3 science classes per room) so students have enough time to prepare/ finish lab ● Small-scale is extra science content based from the standard curriculum= students become more interested ● Some chemical reactions cannot be observed in small-scale so normal scale is used so it must be used both thoroughly ● Most small-scale topics cannot be taught in middle school so they usually do full-scale since the topics are combined (biology, physics, chemistry) ● Sometimes there is not enough time to perform full-scale lab and not all lab instruments are used ● Most students like small-scale because reactions happen faster since it requires smaller amounts of chemicals ● Importance of Small-scale chemistry: <ul style="list-style-type: none"> ● Time Efficient: students/teachers do many activities, so small-scale is implemented ● Cheap ● Easy ● Don't have to use lab room ● Results are pretty similar ● <i>Feedback:</i> <ul style="list-style-type: none"> ○ Target audience: teachers who become instructors (travel to give out training around Thailand) and some teachers who attend the training program ○ DOW should give out more lab kits through their training
3	<ul style="list-style-type: none"> ● Normally I teach full-scale because we have enough instruments, I think grade 11 science topics cannot do sscl ● I want to teach full-scale because using real equipment is important but sscl is also important because 1. Budget 2. Dispose waste but I teach depending on topics (I decide based on the content and the technical skills required) ● I usually sscl when there is a science fair (every year we have science fair and we get students to demonstrate sscl there) ● Students don't get to do a lot of small-scale so they're excited. They also think it's easier

	<ul style="list-style-type: none"> ● Full-scale: They like it but they still need to improve their technical skills and they're pretty anxious because I get strict when I teach them technical skills ● I think both full and small-scale should be applied ● Full-scale is used in volumetric experiment ● Small-scale: change student's perspective in science in a good way. They view full-scale normally but since they rarely see sscl, it pulls their interest to want to do lab ● <i>Feedback:</i> <ul style="list-style-type: none"> ○ We have instruments but I want DOW to come up with more lab topics (like creating more topics + lab kits) ○ Come up with new topics so I can use to teach in class ○ I think small-scale should be more universal. ○ Some science teachers skip the lab because they think it's not important and they think it's easy. So lab should be emphasized because it makes students think that lab is not important, and theory is only needed. ○ Many teachers focus on theory and this creates students for the students when they enter university ○ Teachers want to have small-scale for biology and physics. ○ They want to visit small-scale equipment manufacturing process.
4	<ul style="list-style-type: none"> ● Our school does not have enough small-scale kits for students (7 people per a single kit). ● The school contains up to grade 9. (Middle school) ● Normally, students will not continue their studies in science due to their background ● She is the only science teacher in this school. ● Thanks to DOW, Kids had a chance to do practical learning by using a small-scale lab. ● She thinks that student's interest in science is influenced by lab learning. ● She can adapt and create my lab instrument as appropriate. (Daily waste can be applied to be the lab material) ● She wants to have small-scale lab physics and biology as well.
5	<ul style="list-style-type: none"> ● School previously had two teachers trained by DOW: one moved and one passed ● School has teachers that have been trained by those who attended the

	<p>DOW program</p> <ul style="list-style-type: none"> ● Lab makes students excited, but only uses full-scale ● 5 students per lab group ● Students don't participate equally, most are good but if they don't understand theory then they do not participate ● Full-scale lab takes a lot of time to prepare especially by yourself, ● Large quantity of chemicals is disposed of down the sink, no hood ● Acid/bases and titrations can use lots of lab experiments and are therefore students favorites. ● Teaching process: lesson→ experiment→ lesson→ report ● Didn't want to be a teacher but liked chemistry ● Graduated from faculty of science ● Went back for teaching degree, believed it was a stable job ● Would do experiments more frequently if they were small-scale ● Experiments performed typically once a month, depending on topic ● 35-40 students per class with 9 groups (~4 students per group) ● Waste disposal for full-scale lab: sink with water ● With full-scale sometimes ran out of time to fully complete experiment ● Students are usually bored with theory and calculations but interested after completing an experiment. ● Having a lab changes students mindset ● <i>Feedback:</i> <ul style="list-style-type: none"> ○ Better if DOW can come up with more topics for the kits because it's easier and faster on the teachers ○ Needs to be more convenient to get small-scale equipment ○ More financial support <ul style="list-style-type: none"> ■ School only supports full scale, no budget for small-scale ■ Have to pay out of their pocket since school hasn't approved of small-scale ○ Create kits for other subjects in science
6	<ul style="list-style-type: none"> ● Use small-scale labs depending on topic ● Usually full-scale not enough time ● Small-scale more efficient but does not fit IPST curriculum that has to be followed ● Students become more excited when they do small-scale <ul style="list-style-type: none"> ○ Reaction happens fast which is good when students are impatient ○ Students tend to be more interested when small-scale is implemented ● Students also like small-scale because they don't have enough materials

	<p>for full-scale labs</p> <ul style="list-style-type: none"> ○ Every student gets to interact in groups ● Students compare small and full-scale labs so aren't confused ● Small-scale is cheaper but best to do both small and full-scale because some topics need a full-scale lab
7	<ul style="list-style-type: none"> ● First place in the DOW-CST award ● She gets to teach a specific classroom, so not all students get to do small-scale chemistry ● Waste disposal method: disposed in a waste bottle ● Has taught arts major students before and they seem to be interested in SSCL as well ● Small-scale is more convenient, requires less time and more obvious results, promote positive opinion towards science, promote active learning, students prepare their own set up ● Normal teach theory along with SSCL when full-scale is taught separated from theory ● <i>Feedback:</i> <ul style="list-style-type: none"> ○ DOW could provide lab kits that are more relevant to the standard curriculum (IPST) since teachers don't have enough time to come up/improvise a lab experiment based on what she has to follow to the curriculum ○ Some teachers don't have time to teach lab so they either: skip lab, teach theory and do "dry lab"
8	<ul style="list-style-type: none"> ● Before the DOW's training program-He wondered how it would work. Is a small-scale lab really possible? ● After the DOW's training program- He feels wow! Small-scale is very useful. For instance,the kits are easy to use, daily waste can be applied to the equipment. Small-scale is very useful. For instance,the kits are easy to use, daily waste can be applied to the equipment. ● Normal lab and small-scale lab shared some similarity in term of the concept. Small-scale is a little easier for the preparation process. ● He thinks that students feel excited as they can do it by themselves. ● With DOW's lab, students are more interested as they have a clearer picture of what they are doing. ● <i>Suggestions:</i> the DOW-CST competition topic is too narrow. It would be better if the topic is more open.

I4: Summary of Teacher Interview Responses at Mandarin Hotel

Mandarin Hotel Training Teacher Interview Summary
Do student like the experiments:
<ul style="list-style-type: none"> ● Students liked creating their own experiments (Cambodia) ● The equipment piques student interest as well. <ul style="list-style-type: none"> ○ They are intrigued by “tiny” materials instead of full-scale ● Yes, they like it because all the students get to participate and it can be implemented in the normal classroom. ● Yes, because they can observe the chemical change and it also motivates kids to be more interested in science (Thai). ● Small-scale changes student perspectives ● Students will ask the teacher “when are we going to do an experiment again?” They are eager to do them ● Like to work together
What did you find most useful about the DOW Chemistry Classroom training?
<ul style="list-style-type: none"> ● Ideas on how specific experiments are conducted ● Lots of knowledge to attract students towards science ● Did not gain confidence in science knowledge from the training but allowed students to participate and understand curriculum ● Discusses the small-scale lab with other teachers across Thailand and ASEAN (Thai).
Suggestions for the future of the program:
<ul style="list-style-type: none"> ● Allow teachers not trained by DOW to attend conferences like this ● Have 1 instructor per group instead of 1 instructor for everyone that floats around ● Give more time for training ● Give instructions slower ● There is not a kit suitable for combustion ● Teacher suggestion - teachers should communicate with each other and share ideas ● They want a youtube video or channel and a way of connecting through social media so they can communicate with DOW

- When they go back to Vietnam they sometimes forget the experiments or can't figure out new ways to do them so they want videos and a way of communication to ask questions
 - I also observed a teacher taking a video of the experiment so that she could remember how to do it
- Want a handbook with all of the experiments
- SSC is not the same as full lab so it's hard to ask for help from other teachers or google when trying to come up with new things
- Vietnam does not want to lose touch once they leave!
- Have trained teachers go visit less fortunate schools to teach and give opportunities to kids in remote area.
- They would like DOW to create an official platform for teachers to connect, discuss and share ideas. One indonesean lady was the only chemistry teacher in school and find difficulties to contact others when having inquires in teaching.
- Platform for communication between teachers trained by DOW
- Want a effective workshop as it used to be
- Want to have a trip overseas among DOW's trainers to be in unity.
- Small-scale vs. Large Scale:
- The small quantities make it safer
 - Use 3ml instead of 100ml
- ~60 students per class (one class in vietnam)
 - Small-scale everyone gets kit
 - Large scale not everyone gets to do the experiment because there are too many students per group
- Less time required to prepare and carry out experiments. Before, they were reluctant to do lab, since it would take up to 2 hours, but small-scale allows students to understand scientific concepts within a shorter period of time.
- The Thai curriculum does not require the use of large-scale experiments so the use of the small-scale experiments can be used to teach the curriculum
- Before learning full-scale they only did full-scale, now they so a mix but do small-scale more frequently
- They want a "train the trainer" program involving the presentation part so that they can practice presenting with their companion.

Things they like about small-scale experiments:

- Most useful because you can use surrounding materials from the environment or what already exists in the classroom
- Cheap
- The results are like the full-scale experiment

- Save more time
- Safety

Challenges of small-scale chemistry:

- Not enough kits per student
 - Do experiments in groups of 5-6 students, would prefer groups of 2-3
- It's not part of the national standard curriculum
- Not enough material because it is still expensive. You have to get creative in finding small-scale equipment
- DOW-CST completion is only popular among the outstanding teachers.